DOCUMENT RESUME

ED 220 628 CE 033 512

AUTHOR	Willison, Neal A.; Shelton, James K.
TITLE	Basic Electronics II.
INSTITUTION	Mid-America Vocational Curriculum Consortium, Stillwater, Okla.
PUB DATE	81
NOTE	377p.; For a related document see ED 195 793.
AVAILABLE FROM	Mid America Vocational Curriculum Consortium, 1515 West Sixth Avenue, Stillwater, OK 74074.
EDRS PRICE	MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS	Behavioral Objectives; Course Content; Curriculum Guides; *Electric Circuits; Electricity; Electronic Equipment; *Electronics; Instructional Materials; Learning Activities; Postsecondary Education; Secondary Education; *Semiconductor Devices; Transistors; Transparencies; Units of Study; Vocational Education

ABSTRACT

Designed for use in basic electronics programs, this curriculum guide is comprised of 15 units of instruction. Unit titles are Review of the Nature of Matter and the P-N Junction, Rectifiers, Filters, Special Semiconductor Diodes, Bipolar-Junction Diodes, Bipolar Transistor Circuits, Transistor Amplifiers, Operational Amplifiers, Logic Devices, Logic Systems, Special Semiconductor Devices, Oscillators, Transmitters, Receivers, and Tubes. Each instructional unit includes some or all of the basic components of a unit of instruction: performance objectives, suggested activities for the instructor, information sheets, transparency masters, job sheets, assignment sheets, answers to assignment sheets, tests, and answers to tests. Each unit is planned for more than one lesson or class period of instruction. (YLB)

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ED220628

BASIC
ELECTRONICS II

by
Dr. Neal A. Willison
and
Dr. James K. Shelton

Developed by the
Mid-America Vocational Curriculum Consortium, Inc.

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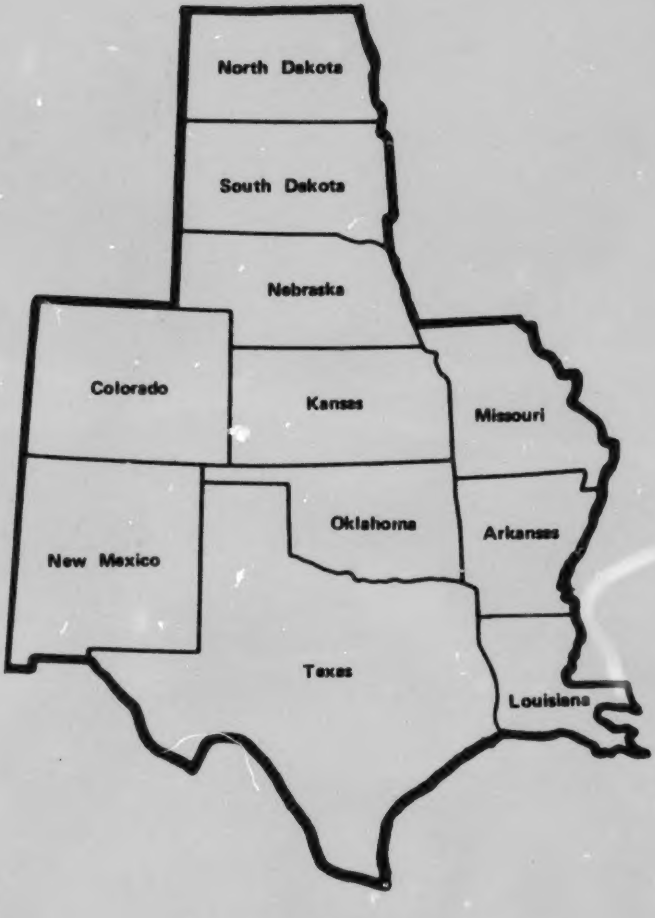
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TABLE OF CONTENTS

Unit I Review of the Nature of Matter and the P-N Junction. . . . . BE II- 1

Unit II Rectifiers. . . . . BE II- 35

Unit III Filters . . . . BE II- 67

Unit IV Special Semiconductor Diodes . . . . BE II- 89

Unit V Bipolar-Junction Diodes . . . . BE II-113

Unit VI Bipolar Transistor Circuits. . . . . BE II-143

Unit VII Transistor Amplifiers. . . . . BE II-183

Unit VIII Operational Amplifiers . . . . BE II-231

Unit IX Logic Devices . . . . BE II-271

Unit X Logic Systems. . . . . BE II-303

Unit XI Special Semiconductor Devices. . . . . BE II-335

Unit XII Oscillators. . . . . BE II-371

Unit XIII Transmitters . . . . BE II-389

Unit XIV Receivers. . . . . BE II-415

Unit XV Tubes . . . . BE II-437

FOREWORD

The Mid-America Vocational Curriculum Consortium (MAVCC) was organized for the purpose of developing instructional material for the eleven member states. Priorities for developing MAVCC material are determined annually based on the needs as identified by all member states. One priority identified was basic electronics. This publication is a part of a project designed to provide the needed instructional material for basic electronics programs.

The success of this publication is due, in large part, to the capabilities of the personnel who worked with its development. The technical writers have numerous years of industry as well as teaching experience. Assisting them in their efforts were representatives of each of the member states who brought with them technical expertise and the experience related to the classroom and to the trade. To assure that the materials would parallel the industry environment and be accepted as a transportable basic teaching tool, organizations and industry representatives were involved in the developmental phases of the manual. Appreciation is extended to them for their valuable contributions.

This publication is designed to assist teachers in improving instruction. As these publications are used, it is hoped that the student performance will improve and that students will be better able to assume a role in their chosen occupation, basic electronics.

Instructional materials in this publication are written in terms of student performance using measurable objectives. This is an innovative approach to teaching that accents and augments the teaching/learning process. Criterion referenced evaluation instruments are provided for uniform measurement of student progress. In addition to evaluating recall information, teachers are encouraged to evaluate the other areas including process and product as indicated at the end of each instructional unit.

It is the sincere belief of the MAVCC personnel and all those members who served on the committee that this publication will allow the students to become better prepared and more effective members of the work force.

David Merrill,
Chairman
Board of Directors
Mid-America Vocational
Curriculum Consortium

PREFACE

For many years those responsible for teaching basic electronics have felt a need for instructional materials to use in this area. A team of teachers, industry representatives, and trade and industrial education staff members accepted this challenge and have produced manuals which will meet the needs of many types of courses where students are expected to become proficient in the area of electronics. The MAVCC *Basic Electronics II* publication is designed to include the basic information needed to be able to attain that proficiency.

As with all efforts of this nature, feedback from the instructors selected to use these curriculum materials will greatly assist MAVCC in evaluating its effort and contribute significantly to plans for future material development.

Every effort has been made to make this publication basic, readable and by all means, usable. Three vital parts of instruction have been intentionally omitted from this publication: motivation, personalization, and localization. These areas are left to the individual instructors and the instructors should capitalize on them. Only then will this publication really become a vital part of the teaching-learning process.

Ann Benson
Executive Director
Mid-America Vocational
Curriculum Consortium, Inc.

for the MAVCC Board of Directors:

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Bob Patton, Oklahoma
Pat Lindley, Texas
Larry Barnhardt, North Dakota
Alan Morgan, New Mexico

ACKNOWLEDGMENTS

Appreciation is extended to those individuals who contributed their time and talents to the development of *Basic Electronics II*.

The contents of this publication were planned and reviewed by:

Robert Laches	Mandan, North Dakota
Carl Jones	Ozark, Arkansas
L. A. Stachura	Lincoln, Nebraska
Al Davis	Robeline, Louisiana
Gary Johnston	Clovis, New Mexico
Ralph T. Albin	Kirksville, Missouri
Dale Postel	Nevada, Missouri
Norman A. Pederson	Sioux Falls, South Dakota
Jesse J. Symms	Dickinson, Texas
Ralph D. Biddle	Tecumseh, Oklahoma
Norbert J. Atherton	Wichita, Kansas
Harry Matsunaka	Fort Collins, Colorado
Howie DiBlasi	Lake Havasu, Arizona
Joe Johnson	Harrison, Arkansas
L. Paul Robertson	Albuquerque, New Mexico

Thanks are extended to Richard Tinnell, Teacher Educator from Oklahoma State University and David Merrill, State Supervisor of Technical and Industrial Education, South Dakota, for their assistance and input into the development of this publication.

Special thanks are extended to Mel Winegarten, of the Electrician's Joint Apprenticeship and Training Committee, Tulsa, Oklahoma for his contributions to the development of this book.

Gratitude is expressed to Bill Reeves, Dan Fulkerson, and Kathy Dolan for editing; to Wendy Rodebaugh, Teddi Cox, Terry Stanley, Rose Primeaux, and Beth Renwick for typing; and to Gloria Koch for phototypesetting.

Appreciation is extended to Vance Story, Bill Dunn, Robert Randall, Lin Thurston, Nancy Hilley, Kim Hale, Edith Mekis, and Carrie Williams for the illustrations and drawings used in this publication.

USE OF THIS PUBLICATION

Instructional Units

The *Basic Electronics II* curriculum includes 15 units. Each instructional unit includes some or all of the basic components of a unit of instruction: performance objectives, suggested activities for teachers and students, information sheets, assignment sheets, visual aids, tests, and answers to the test. Units are planned for more than one lesson or class period of instruction.

Careful study of each instructional unit by the teacher will help to determine:

A. The amount of material that can be covered in each class period
B. The skills which must be demonstrated
  1. Supplies needed
  2. Equipment needed
  3. Amount of practice needed
  4. Amount of class time needed for demonstrations
C. Supplementary materials such as pamphlets or filmstrips that must be ordered
D. Resource people who must be contacted

Objectives

Each unit of instruction is based on performance objectives. These objectives state the goals of the course, thus providing a sense of direction and accomplishment for the student.

Performance objectives are stated in two forms: unit objectives, stating the subject matter to be covered in a unit of instruction; and specific objectives, stating the student performance necessary to reach the unit objective.

Since the objectives of the unit provide direction for the teaching-learning process, it is important for the teacher and students to have a common understanding of the intent of the objectives. A limited number of performance terms have been used in the objectives for this curriculum to assist in promoting the effectiveness of the communication among all individuals using the materials.

Following is a list of performance terms and their synonyms which may have been used in this material:

Name
Label
List in writing
List orally
Letter
Record
Repeat
Give

Identify
Select
Mark
Point out
Pick out
Choose
Locate

Describe
Define
Discuss in writing
Discuss orally
Interpret
Tell how
Tell what
Explain

Order
Arrange
Sequence
List in order
Classify
Divide
Isolate
Sort

Distinguish
Discriminate

Construct
Draw
Make
Build
Design
Formulate
Reproduce
Transcribe
Reduce
Increase
Figure

Demonstrate
Show your work
Show procedure
Perform an experiment
Perform the steps
Operate
Remove
Replace
Turn off/on
(Dis) assemble
(Dis) connect

Additional Terms Used
Evaluate
Complete
Analyze
Calculate
Estimate
Plan
Observe
Compare
Determine
Perform

Prepare
Make
Read
Tell
Teach
Converse
Lead
State
Write

Reading of the objectives by the student should be followed by a class discussion to answer any questions concerning performance requirements for each instructional unit.

Teachers should feel free to add objectives which will fit the material to the needs of the students and community. When teachers add objectives, they should remember to supply the needed information, assignment and/or job sheets, and criterion tests.

Suggested Activities for the Instructor:

Each unit of instruction has a suggested activities sheet outlining steps to follow in accomplishing specific objectives. Duties of instructors will vary according to the particular unit; however, for best use of the material they should include the following: provide students with objective sheet, information sheet, assignment sheets, and job sheets; preview filmstrips, make transparencies, and arrange for resource materials and people; discuss unit and specific objectives and information sheet; give test. Teachers are encouraged to use any additional instructional activities and teaching methods to aid students in accomplishing the objectives.

Information Sheets

Information sheets provide content essential for meeting the cognitive (knowledge) objectives in the unit. The teacher will find that the information sheets serve as an excellent guide for presenting the background knowledge necessary to develop the skill specified In the unit objective.

Students should read the information sheets before the information is discussed in class. Students may take additional notes on the information sheets.

Transparency Masters

Transparency masters provide information in a special way. The students may see as well as hear the material being presented, thus reinforcing the learning process. Transparencies may present new information or they may reinforce information presented in the information sheets. They are particularly effective when identification is necessary.

Transparencies should be made and placed in the notebook where they will be immediately available for use. Transparencies direct the class's attention to the topic of discussion. They should be left on the screen only when topics shown are under discussion.

Job Sheets

Job sheets are an important segment of each unit. The instructor should be able to and in most situations should demonstrate the skills outlined in the job sheets. Procedures outlined in the job sheets give direction to the skill being taught and allow both student and teacher to check student progress toward the accomplishment of the skill. Job sheets provide a ready outline for students to follow if they have missed a demonstration. Job sheets also furnish potential employers with a picture of the skills being taught and the performances which might reasonably be expected from a person who has had this training.

Assignment Sheets

Assignment sheets give direction to study and furnish practice for paper and pencil activities to develop the knowledges which are necessary prerequisites to skill development. These may be given to the student for completion in class or used for homework assignments. Answer sheets are provided which may be used by the student and/or teacher for checking student progress.

Test and Evaluation

Paper-pencil and performance tests have been constructed to measure student achievement of each objective listed in the unit of instruction. Individual test items may be pulled out and used as a short test to determine student achievement of a particular objective. This kind of testing may be used as a daily quiz and will help the teacher spot difficulties being encountered by students in their efforts to accomplish the unit objective. Test items for objectives added by the teacher should be constructed and added to the test.

Test Answers

Test answers are provided for each unit. These may be used by the teacher and/or student for checking student achievement of the objectives.

BASIC ELECTRONICS II

INSTRUCTIONAL/TASK ANALYSIS

<table>
<tr><th>JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)</th><th>RELATED INFORMATION: What the Worker Should Know (Cognitive)</th></tr>
<tr><td colspan="2">UNIT I: REVIEW OF THE NATURE OF MATTER AND THE P-N JUNCTION</td></tr>
<tr><td></td><td>1. Terms</td></tr>
<tr><td></td><td>2. Components of an atomic model</td></tr>
<tr><td></td><td>3. Types of bonding</td></tr>
<tr><td></td><td>4. Semiconductor crystal structures</td></tr>
<tr><td></td><td>5. Majority and minority carriers</td></tr>
<tr><td></td><td>6. Components of a P-N junction</td></tr>
<tr><td></td><td>7. P-N junction polarity</td></tr>
<tr><td></td><td>8. P-N junction characteristic curves</td></tr>
<tr><td>9. Draw schematic symbols</td><td></td></tr>
<tr><td>10. Perform static test on semi-conductor diodes</td><td></td></tr>
<tr><td>11. Plot characteristic curves</td><td></td></tr>
<tr><td colspan="2">UNIT II: RECTIFIERS</td></tr>
<tr><td></td><td>1. Terms</td></tr>
<tr><td></td><td>2. Input and output waveforms</td></tr>
<tr><td></td><td>3. Formulas for average and DC output voltage</td></tr>
<tr><td></td><td>4. Conventional full-wave rectifiers and full-wave bridge rectifiers</td></tr>
<tr><td></td><td>5. Formulas for average and peak DC output voltage</td></tr>
<tr><td></td><td>6. DC output voltage of a multiplier circuit</td></tr>
<tr><td>7. Calculate average DC voltage</td><td></td></tr>
<tr><td>8. Draw current flow in a specified rectifier</td><td></td></tr>
</table>

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)

RELATED INFORMATION: What the Worker Should Know (Cognitive)

9. Construct and test a half-wave rectifier circuit
10. Construct and test a full-wave bridge rectifier circuit
11. Construct and test a voltage doubler circuit

UNIT III: FILTERS

1. Terms
2. Purposes of filters
3. Voltage waveshapes
4. Basic filter types
5. Basic filter configurations
6. Ripple factor
7. Calculate ripple factor and percent regulation
8. Construct and test a capacitor filter circuit
9. Construct and test a Pi-section filter circuit

UNIT IV: SPECIAL SEMICONDUCTOR DIODES

1. Terms
2. Schematic symbols
3. Components of a zener diode
4. Applications of zener diodes
5. Components of tunnel diodes
6. Applications of tunnel diodes
7. Bias voltage and barrier capacitance in varactor diodes
8. Applications of varactor diodes
9. Instantaneous forward current in light-emitting diodes
10. Applications of light-emitting diodes

JOB TRAINING: What the Worker Should Be Able to Do
(Psychomotor)

RELATED INFORMATION: What the Worker Should Know
(Cognitive)

UNIT V: TRANSISTORS

1. Terms
2. Basics of PNP and NPN transistors
3. Major uses of transistors
4. Voltage drop for germanuim and silicon transistors
5. Biasing arrangements for PNP and NPN transistors
6. Typical types of transistors
7. Label a transistor circuit
8. Test transistors

UNIT VI: BIPOLAR-JUNCTION TRANSISTOR CIRCUITS

1. Terms
2. Basic types of transistor circuits
3. Circuit current gain
4. Gain characteristics
5. Signal voltage phase reversal
6. Applications of transistor circuits
7. Impedances for basic transistor circuits
8. Compute stage gain in decibels
9. Construct and test a common-emitter circuit
10. Construct and test a common-base circuit
11. Construct and test a common-collector circuit
12. Plot a transistor output characteristic curve

UNIT VII: TRANSISTOR AMPLIFIERS

JOB TRAINING: What the Workers Should Be Able to Do (Psychomotor)	RELATED INFORMATION: What the Worker Should Know (Cognitive)
	1. Terms
	2. Voltage divider bias circuit
	3. Leakage current
	4. Classes of amplifiers
	5. Class B push-pull amplifiers
	6. Darlington-pair circuits
	7. Common-emitter Class A amplifier circuits
	8. Types of coupling
	9. Stage gains in overall amplifier gain
	10. Load-line
	11. Multistage-amplifier circuits
12. Test a single-ended amplifier	
13. Test a push-pull amplifier	
14. Test a two stage amplifier	
15. Test a Darlington-pair amplifier	

UNIT VIII: OPERATIONAL AMPLIFIERS

JOB TRAINING: What the Workers Should Be Able to Do (Psychomotor)	RELATED INFORMATION: What the Worker Should Know (Cognitive)
	1. Terms
	2. Categories of integrated circuits
	3. Characteristics of inverting and noninverting operational amplifiers
	4. DC summing inverting and differential amplifiers
5. Calculate closed-loop gain	
6. Calculate output voltage	
7. Construct and test an inverting amplifier	
8. Construct and test a noninverting amplifier	
9. Construct and test a DC summing inverting amplifier	
10. Construct and test a differential amplifier	

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)	RELATED INFORMATION: What the Worker Should Know (Cognitive)
UNIT IX	
	1. Terms
	2. Schematic symbols
	3. Truth tables
4. Construct and test an IC "AND" gate circuit	
5. Construct and test an IC "OR" gate circuit	
6. Construct and test an IC "NAND" gate circuit	
7. Construct and test an IC "Exclusive-OR" gate circuit	
8. Construct and test a diode "AND" gate circuit	
9. Construct and test a diode-transistor "NOR" gate circuit	
UNIT X: LOGIC SYSTEMS	
	1. Terms
	2. Binary numbers
	3. Truth table for half-adder
	4. Multivibrators
5. Convert decimals to BCD	
6. Add binary numbers	
7. Construct and test a four-bit shift register	
UNIT XI: SPECIAL SEMICONDUCTOR DEVICES	
	1. Terms
	2. SCR characteristic curves
	3. Triacs
	4. Diac applications
	5. Thermistor types
	6. UJT characteristic curves
	7. JFET characteristic curves

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)	RELATED INFORMATION: What the Worker Should Know (Cognitive)
	8. Types of MOFETs
	9. Types of IGFETs
	10. Construct and test silicon-controlled rectifier circuits
	11. Construct and test a unijunction transistor relaxation oscillator
	12. Construct and test a field-effect transistor amplifier
	13. Construct and test a thermistor-control circuit

UNIT XII: OSCILLATORS

	1. Terms
	2. Oscillator schematic diagrams
3. Construct and test a Hartley oscillator	

UNIT XIII: TRANSMITTERS

	1. Terms
	2. CW transmitter stages
	3. AM broadcast transmitter stages
	4. FM broadcast transmitter stages
	5. Television transmitting system stages
	6. Characteristics of antennas
7. Calculate wavelength and antenna length	

UNIT XIV: RECIEVERS

	1. Terms
	2. AM receiver stages
	3. FM receiver stages
	4. Frequency ranges
	5. FCC responsibilities

JOB TRAINING: What the Worker Should Be Able to Do
(Psychomotor)

RELATED INFORMATION: What the Worker Should Know
(Cognitive)

6. RF amplifier stages

7. Output frequencies

8. IF amplifier stages

9. Limiter stage

10. FM detection circuits

11. Locate and identify the major stages of AM/FM receivers

UNIT XV: ELECTRON TUBES

1. Terms

2. Schematic symbols

3. Pin numbers

4. Vacuum tube characteristic curves

5. Construct and test a vacuum tube diode circuit

REVIEW OF THE NATURE OF MATTER AND THE P-N JUNCTION
UNIT I

UNIT OBJECTIVE

After completion of this unit the student should be able to match terms and definitions associated with matter and the P-N junction, describe the forward and reverse characteristics of a P-N junction diode, construct and test a semiconductor diode circuit and plot the diode characteristic curves. This knowledge will be evidenced by correctly performing the procedures outlined in the job sheet and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to the nature of matter and the P-N junction with their correct definitions.
2. Label the nucleus, protons, neutrons, electrons, and the valence shell of an atomic model.
3. Match types of bonding with their materials.
4. Identify semiconductor crystal structures.
5. State the majority and minority carriers and their electrical polarity in N-type and P-type semiconductors.
6. Complete a list of four methods and techniques used to manufacture a P-N junction.
7. Sketch a P-N junction and label the P material, the N material, the depletion region, and the barrier potential showing voltage ranges for the silicon and germanium diodes.
8. Label the proper polarity for a reverse-biased P-N junction and a forward-biased P-N junction.
9. Draw the schematic symbol for a diode, label the cathode, the anode and show the electrical polarity of each terminal to forward bias the device.
10. Identify, from the P-N junction diode characteristic curves, the forward-bias region, the reverse-bias region, the majority carriers, and the minority carriers.
11. Demonstrate the ability to:
    a. Perform a static test on semiconductor diodes.
    b. Test a semiconductor diode and plot the characteristic curves.

REVIEW OF THE NATURE OF MATTER
AND THE P-N JUNCTION
UNIT I

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information and job sheets.

III. Make transparencies.

IV. Discuss unit and specific objectives.

V. Discuss information sheets.

VI. Demonstrate and discuss the procedures outlined in the job sheets.

VII. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

   A. Objective sheet

   B. Information sheet

   C. Transparency masters

      1. TM 1--Atomic Model

      2. TM 2--Semiconductor Crystal Structures

      3. TM 3--P-N Junction

      4. TM 4--Forward and Reverse Bias

      5. TM 5--P-N Junction Diode Characteristic Curves

   D. Job sheets

      1. Job Sheet #1--Perform a Static Test of Semiconductor Diodes

      2. Job Sheet #2--Test a Semiconductor Diode and Plot the Characteristic Curves

   F. Test

   G. Answers to test

II. Reference--Grob, Bernard. *Basic Electronics*. Third Edition. New York: McGraw-Hill, 1971.

REVIEW OF THE NATURE OF MATTER
AND THE P-N JUNCTION
UNIT I

INFORMATION SHEET

I. Terms and definitions

A. Atom--The smallest particle of an element containing electrons, protons, and neutrons

B. Nucleus--The core of the atom which contains two major particles, protons and neutrons

C. Proton--An elementary atomic particle within the nucleus with a positive electrical charge

D. Electron--An elementary atomic particle in orbit around the nucleus with a negative electrical charge

E. Neutron--An elementary atomic particle within the nucleus with no electrical charge

F. Shell--One of the orbital or energy levels of the electrons about the nucleus

G. Valence number--The number of electrons in the outermost orbital shell (valence shell) of an atom

H. Covalent bonding--Two or more atoms sharing electrons in their outer shell to form a stable molecule

I. Intrinsic material--A pure crystal of a material

J. Extrinsic material--An intrinsic material to which an impurity has been added

K. Insulator--A material with very few or no free electrons in the valence shell

(NOTE: This normally includes Valence Groups I to III.)

L. Conductor--A material that has 1 or 2 electrons in the valance shell that are not tightly bound to the nuclei

(NOTE: This normally includes Valence Groups II to VIII.)

M. Semiconductor--A material in which the valence shell is partially filled with electrons which can be removed when some form of energy is applied to the material

(NOTE: This normally includes Valence Group IV.)

N. Doping--The process of adding impurities to an intrinsic material

INFORMATION SHEET

O. P-N junction--The region where N-type and P-type semiconductor material join together

P. Bias--External electric potential (voltage) applied to a P-N junction

Q. Diode--A two-terminal device consisting of a P-N junction which allows majority carriers to flow in one direction

R. Bonding--The holding together of atoms to form a molecule

S. Majority carriers--Electrons in N-type material and holes in P-type material

T. Minority carriers--Electrons in P-type material and holes in N-type material

U. Holes--The absence of electrons in a covalent bond

V. Peak inverse voltage (PIV or PRV)--The maximum reverse-bias voltage which can be applied to a P-N junction without damage to the junction

W. Depletion region--The junction area that has no free charges

II. Atomic model (Transparency 1)

A. Nucleus

B. Proton

C. Neutron

D. Electron

E. Valence shell

III. Types of bonding and their materials

A. Covalent--Insulators and semiconductors

B. Ionic--Gases

C. Metallic--Conductors

IV. Semiconductor crystal structures (Transparency 2)

A. Intrinsic--Pure semiconductor crystal

B. Extrinsic--N-type semiconductor crystal

1. Impurity

2. Free electron

INFORMATION SHEET

C. Extrinsic--P-type semiconductor crystal

1. Impurity

2. Hole

V. Majority and minority carriers and their electrical polarity

A. N-type

1. Majority carriers--Electrons, negative charge

2. Minority carriers--Holes, positive charge

B. P-type

1. Majority carriers--Holes, positive charge

2. Minority carriers--Electrons, negative charge

VI. P-N junction manufacturing methods and techniques

A. Molten method or grown-junction technique

B. Epitaxial-growth method

C. Diffusion method

D. Alloy method

VII. Depletion or barrier region of a P-N junction and the barrier potential (Transparency 3)

A. Silicon diode barrier potential = 0.6 to 0.7 volts

B. Germanium diode barrier potential = 0.2 to 0.3 volts

VIII. P-N junction bias (Transparency 4)

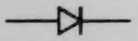
A. Reverse bias--Positive battery terminal connected to N-type material

B. Forward bias--Positive battery terminal connected to the P-type material

IX. Diode schematic symbols (Transparency 5)

A. Anode + P-section

B. Cathode - N-secton

C. Symbol-- 

(NOTE: The arrow points to the N-type material.)

INFORMATION SHEET

X. P-N junction diode characteristic curves (Transparency 5)

   A. Forward-bias region

   B. Reverse-bias region

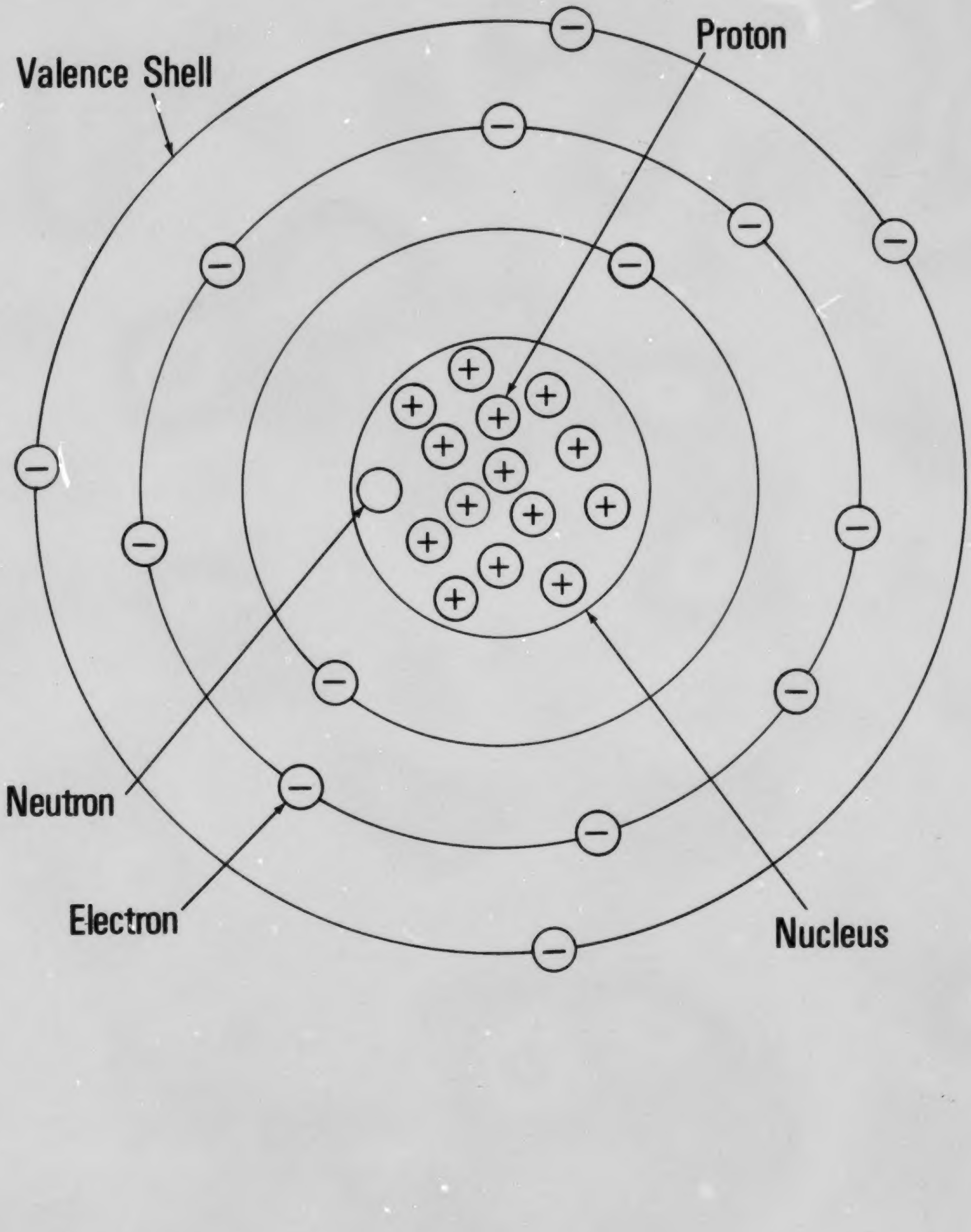
   C. Majority carriers

   D. Minority carriers

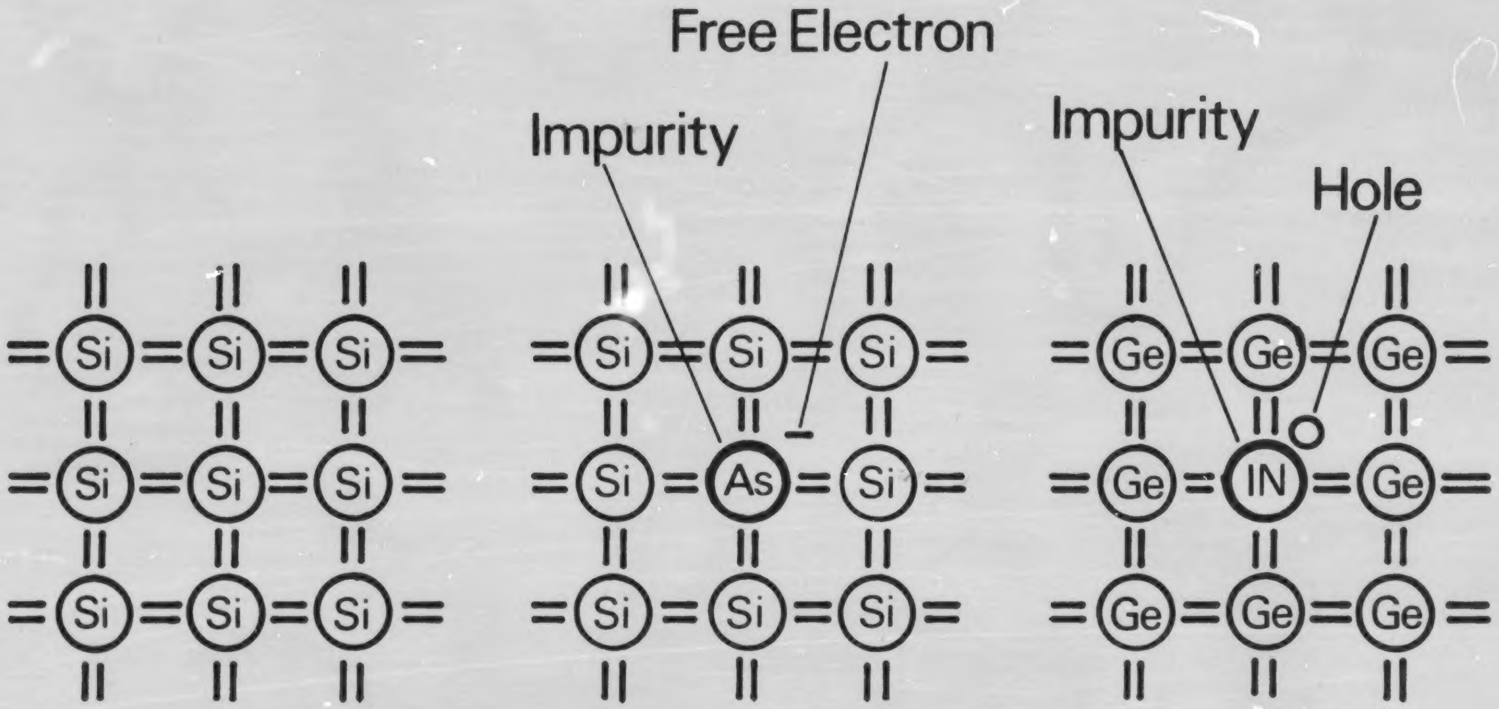
   E. Breakdown

   (NOTE: Breakdown occurs when PIV is exceeded.)

Atomic Model (Silicon)


Valence Shell
Proton
Neutron
Electron
Nucleus

Semiconductor Crystal Structures

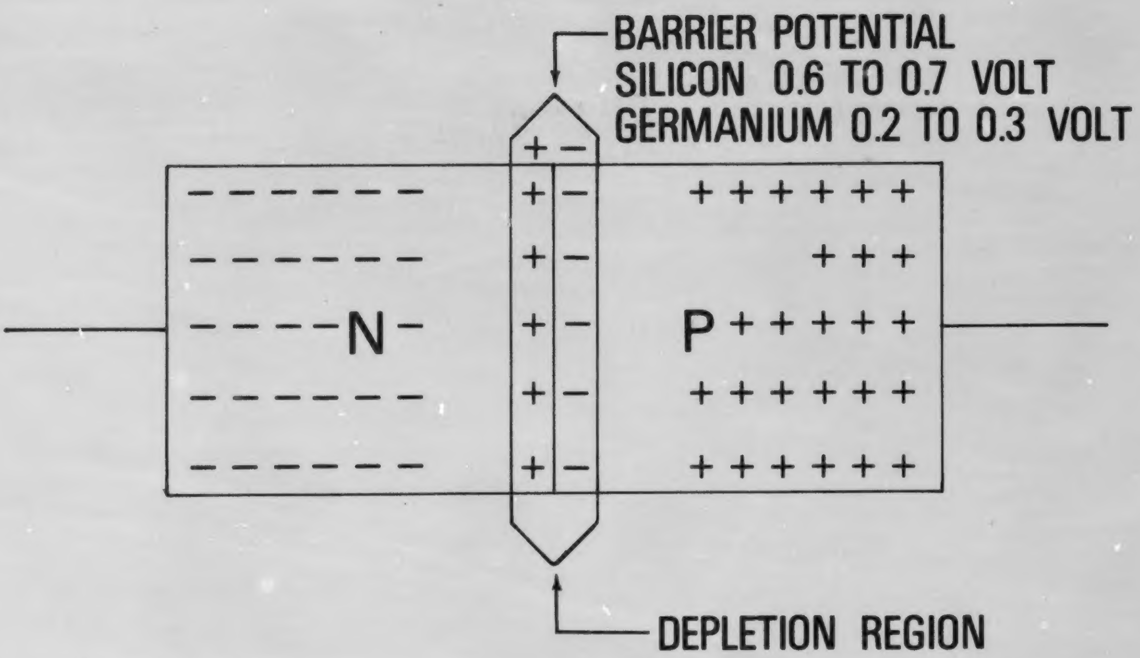

Free Electron
Impurity
Impurity
Hole
Si
As
Ge
IN
−

Pure Silicon Crystal
Intrinsic

N-Type Silicon
Crystal
Extrinsic

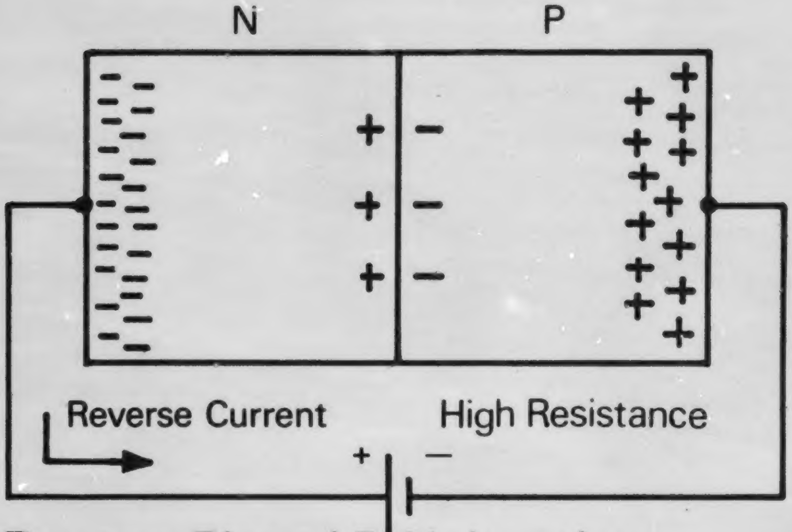
P-Type Germanium
Crystal
Extrinsic

P-N Junction

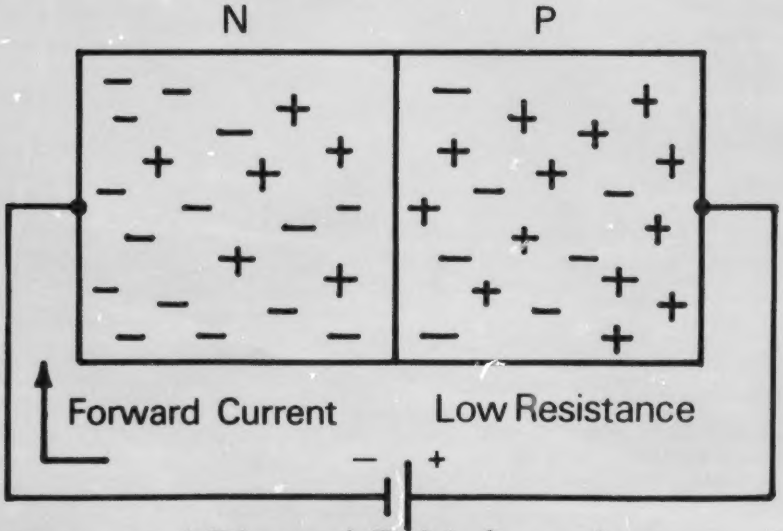

BARRIER POTENTIAL
SILICON 0.6 TO 0.7 VOLT
GERMANIUM 0.2 TO 0.3 VOLT
N
P
DEPLETION REGION

P-N JUNCTION
Showing Barrier Potential
And
Depletion Region

Forward and Reverse Bias


N
P
Reverse Current
High Resistance
+
–

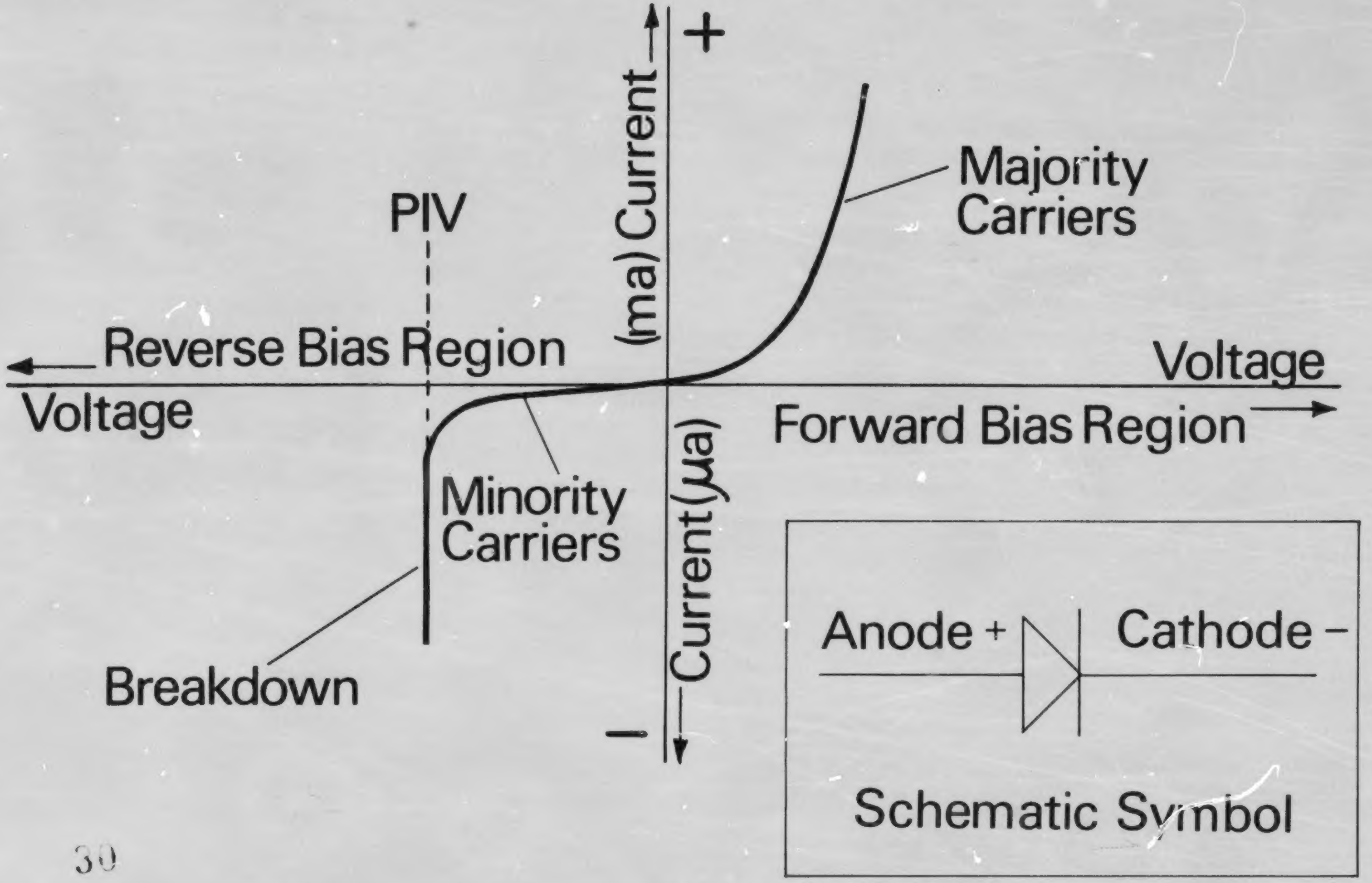
Reverse Biased P-N Junction


N
P
Forward Current
Low Resistance
–
+

Forward Biased P-N Junction

(Note— Barrier potential increases and depletion region widens as reverse bias is increased.)

P-N Junction Diode Characteristic Curves


+
(ma) Current
Majority Carriers
PIV
Reverse Bias Region
Voltage
Voltage
Forward Bias Region
Minority Carriers
Current (μa)
Breakdown
−
Anode +
Cathode −
Schematic Symbol

REVIEW OF THE NATURE OF MATTER AND THE P-N JUNCTION
UNIT I

JOB SHEET #1--PERFORM A STATIC TEST OF SEMICONDUCTOR DIODES

I. Tools and equipment

   A. 2 multimeters

   B. 3 different types of diodes from your instructor

II. Procedure

   A. Determine the polarity of your ohmmeter leads by connecting them to a voltmeter

   B. Mark the polarity of the ohmmeter leads

   C. Connect the positive lead of the ohmmeter to the anode of the diode and the negative lead of the ohmmeter to the cathode of the diode.

   D. Read and record the ohmmeter reading in the data table

   (NOTE: The ohmmeter should be on a R x 100 scale to avoid possible damage to the diode.)

   E. Reverse the ohmmeter connection to the diode, read and record the ohmmeter reading

   F. Determine from the ohmmeter reading whether the diode is good or bad

   (NOTE: A good diode will have a low ohmic reading in the forward-biased direction and a high ohmic reading when reversed biased.)

   G. Repeat the above procedure for each of your diodes

DATA TABLE I - STATIC TEST

DIODE	FORWARD RESISTANCE	REVERSE RESISTANCE	GOOD OR BAD
D_1			
D_2			
D_3			
D_4			

REVIEW OF THE NATURE OF MATTER
AND THE P-N JUNCTION
UNIT I

JOB SHEET #2–TEST A SEMICONDUCTOR DIODE AND PLOT THE CHARACTERISTIC CURVES

I. Tools and equipment

A. Variable DC power supply (0-30 volts)

B. 1-220 ohm, 5 Watt resistor

C. 1-silicon diode (1N914 or equivalent) optional germanium diode

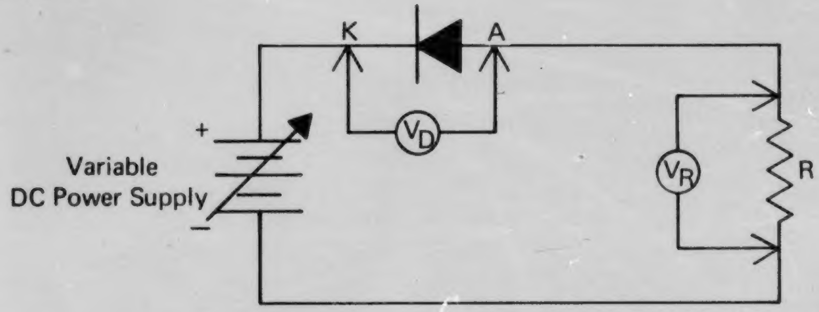
D. 2-multimeters

E. Graph paper

II. Procedure

A. Connect the following circuit for a reverse-biased diode but do not apply power

(NOTE: Connect the multimeters as voltmeters and observe the proper polarity.)



B. Apply power

C. Read and record V_D (voltage across the diode) and V_R (voltage across the resistor) when the power supply is set at 0, 1, 2, 3, 4, 5, 10, 15, 20, and 25 volts

(NOTE: The peak inverse voltage rating of the diode must be equal to or greater than 25 volts.)

D. Turn the power supply off

E. Reverse the diode connection in the circuit so it will be forward biased

F. Read and record V_D and V_R for power supply settings of 0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.0, 2, 4, volts

JOB SHEET #2

G. Compute the current flowing in the circuit for each reading taken in steps B and E

H. Draw a graph of the diode forward and reverse characteristic curve

(NOTE: The horizontal axis should be V_D and the vertical axis should be I_D.)

I. Check your calculations and your graph with your instructor.

JOB SHEET #2

DATA TABLES

TABLE I - REVERSE BIAS

V Supply	0_V	1_V	2_V	3_V	4_V	5_V	10_V	15_V	20_V	25_V
V_O										
V_R										

TABLE II - FORWARD BIAS

V Supply	0.0	$.1_V$	$.2_V$	$.3_V$	$.4_V$	$.5_V$	$.6_V$	$.7_V$	$.8_V$	$.9_V$	1.0_V	2.0_V	4.0_V
V_D													
V_R													

REVIEW OF THE NATURE OF MATTER
AND THE P-N JUNCTION
UNIT I

NAME________________________________

TEST

1. Match the terms on the right with their correct definitions.

_____ a. Two or more atoms sharing electrons in their outer shell to form a stable molecule

_____ b. The smallest particle of an element containing electrons, protons, and neutrons

_____ c. The number of electrons in the outermost orbital shell of an atom

_____ d. The core of the atom which contains two major particles, protons and neutrons

_____ e. One of the orbital or energy levels of the electrons about the nucleus

_____ f. An elementary atomic particle within the nucleus with a positive electrical charge

_____ g. An elementary atomic particle within the nucleus with no electrical charge

_____ h. An elementary atomic particle in orbit around the nucleus with a negative electrical charge

_____ i. An intrinsic material to which an impurity has been added

_____ j. A two-terminal device consisting of a P-N junction which allows majority carriers to flow in one direction

_____ k. External electric potential applied to a P-N junction

_____ l. The region where N-type and P-type semiconductor material join together

_____ m. The process of adding impurities to an intrinsic material

_____ n. A material in which the valence shell is partially filled with electrons which can be removed when some form of energy is applied to the material

1. Atom
2. Nucleus
3. Proton
4. Electron
5. Neutron
6. Shell
7. Valence number
8. Covalent bonding
9. Insulator
10. Intrinsic material
11. Extrinsic material
12. Diode
13. Bias
14. P-N junction
15. Doping
16. Conductor
17. Semiconductor
18. Bonding
19. Majority carriers
20. Minority carriers
21. Holes
22. Depletion region
23. Peak inverse voltage

_____o. A material that has 1 or 2 electrons in the valence shell that are not tightly bound to the nuclei

_____p. A material with very few or no free electrons in the valence shell

_____q. A pure crystal of a material

_____r. The absence of electrons in a covalent bond

_____s. Electrons in P-type material and holes in N-type material

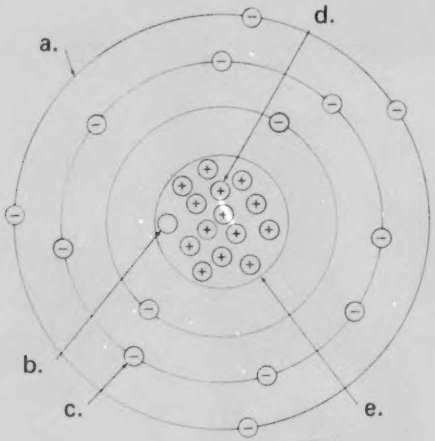
_____t. The holding together of atoms to form a molecule

_____u. Electrons in N-type material and holes in P-type material

_____v. The maximum reverse-bias voltage which can be applied to a P-N junction without damage to the junction

_____w. The junction area that has no free charges

2. Label the nucleus, protons, neutrons, electrons, and the valence shell of the atomic model given below.



a.___________________________ c.___________________________

b.___________________________ d.___________________________

e.___________________________

3. Match types of bonding on the right with the materials to which they apply.

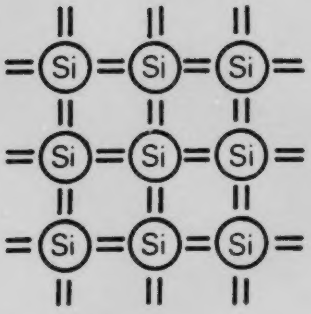
_____a. Conductors

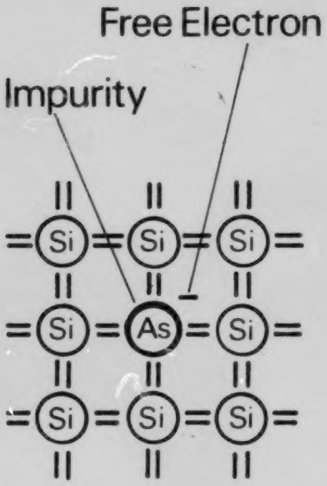
_____b. Gases

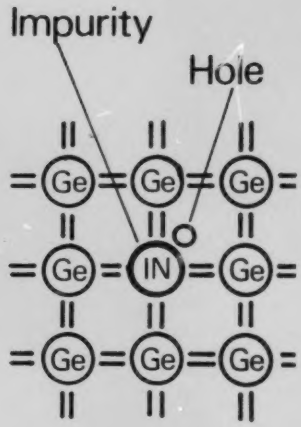
_____c. Insulators and semiconductors

1. Covalent
2. Ionic
3. Metallic

4. Identify an intrinsic silicon crystal, an extrinsic N-type silicon crystal, and an extrinsic P-type germanium crystal.







a. ____________ b. ____________ c. ____________

5. State the majority and minority carriers and their electrical polarity in N-type and P-type semiconductors.

N-type

a. Majority carriers are ______________________________

b. Minority carriers are ______________________________

P-type

a. Majority carriers are ______________________________

b. Minority carriers are ______________________________

6. Complete a list of four methods and techniques used to manufacture a P-N junction.

   a. Molten method or grown-junction technique

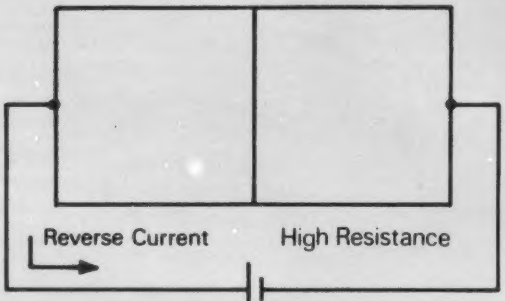
   b. Expitaxial-growth method

   c. ______________________________

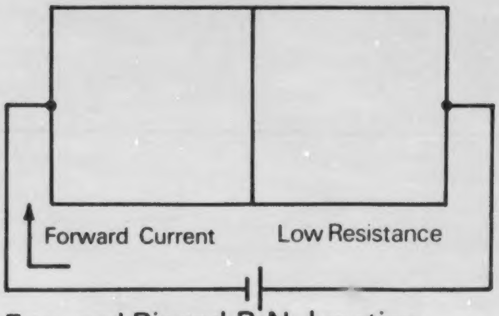
   d. ______________________________

7. Sketch a P-N junction and label the P material, the N material, the depletion region, and the barrier potential showing voltage ranges for the silicon and germanium diodes.

8. Label the proper polarity for the reverse-biased P-N junction and the forward-baised P-N junction in the following illustrations.


Reverse Current
High Resistance

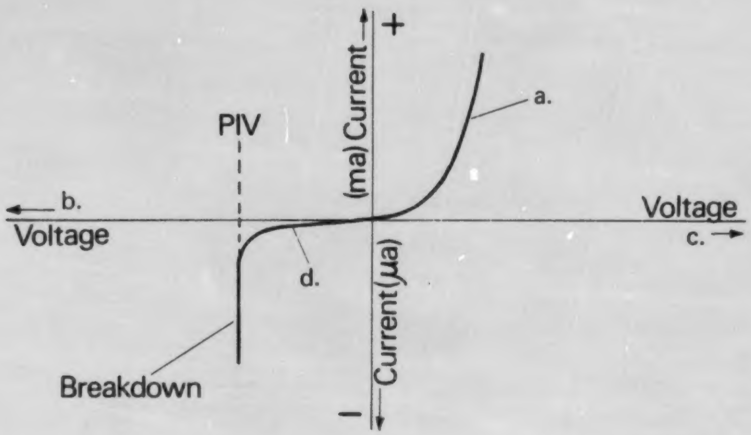
Reverse Biased P-N Junction


Forward Current
Low Resistance

Forward Biased P-N Junction

9. Draw the schematic symbol for a diode, label the cathode, the anode and show the electrical polarity to forward bias the device.

10. Identify, from the following P-N junction diode characteristic curves, the forward-bias region, the reverse-bias region, the majority carriers, and the minority carriers.


+
(ma) Current
a.
PIV
b.
Voltage
Voltage
c.
d.
Current (μa)
Breakdown
–

a. ______________________ c. ______________________

b. ______________________ d. ______________________

11. Demonstrate the ability to:

    a. Perform a static check of semiconductor diodes.

    b. Test a semiconductor diode and plot the characteristic curves.

    (NOTE: If these activities have not been accomplished prior to test, ask your instructor when they should be completed.)

REVIEW OF THE NATURE OF MATTER AND THE P-N JUNCTION

UNIT I

ANSWERS TO TEST

1. a. 8
   b. 1
   c. 7
   d. 2
   e. 6
   f. 3
   g. 5
   h. 4
   i. 11
   j. 12
   k. 13
   l. 14
   m. 15
   n. 17
   o. 16
   p. 9
   q. 10
   r. 21
   s. 20
   t. 18
   u. 19
   v. 23
   w. 22

2. a. Valence shell
   b. Neutron
   c. Electron
   d. Proton
   e. Nucleus

3. a. 3
   b. 2
   c. 1

4. a. Intrinsic silicon crystal
   b. Extrinsic N-type silicon crystal
   c. Extrinsic P-type germanium crystal

5. N-type

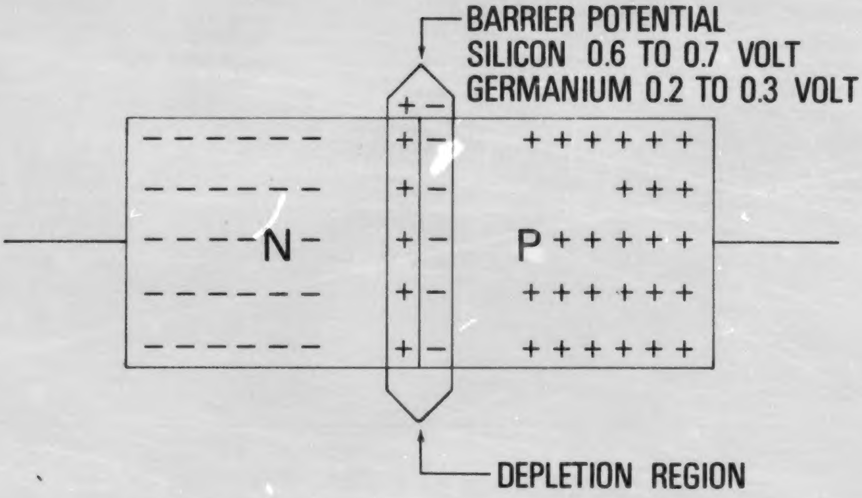
   a. Electrons, negative charge
   b. Holes, positive charge

   P-type

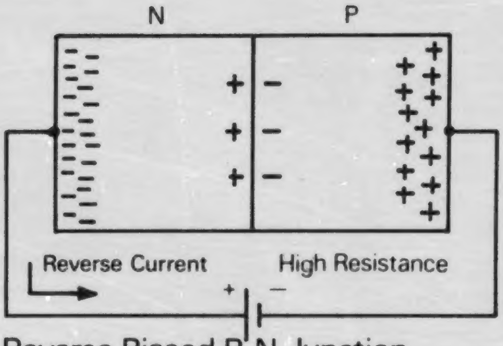
   a. Holes, positive charge
   b. Electrons, negative charge

6. c. Diffusion method
   d. Alloy method

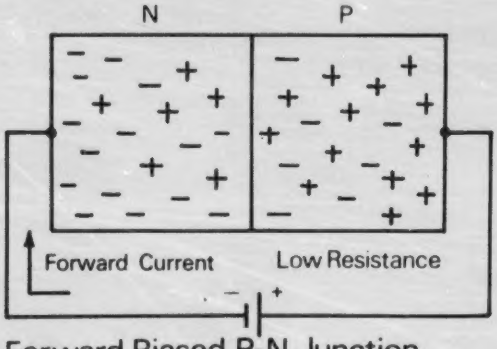
7.


BARRIER POTENTIAL
SILICON 0.6 TO 0.7 VOLT
GERMANIUM 0.2 TO 0.3 VOLT
N
P
DEPLETION REGION

8.

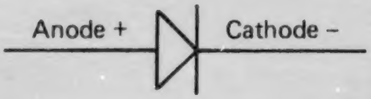

N
P
Reverse Current
High Resistance
+
–

Reverse Biased P-N Junction


N
P
Forward Current
Low Resistance
–
+

Forward Biased P-N Junction

9.



10. a. Majority Carriers
    b. Reverse-bias region
    c. Forward-bias region
    d. Minority carriers

11. Performance skills evaluated to the satisfaction of the instructor

RECTIFIERS
UNIT II

UNIT OBJECTIVE

After completion of this unit, the student should be able to state the formula which relates peak input voltage to average DC output voltage, identify conventional half-wave and full-wave rectifier circuits, and construct and test a half-wave rectifier, a full-wave rectifier, and a voltage multiplier circuit. This knowledge will be evidenced by correctly performing the procedures outlined in the assignment and job sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to rectifiers with their correct definitions.
2. Sketch the input and output waveforms for a basic half-wave rectifier circuit.
3. State the formulas for the average and peak DC output voltage of a half-wave rectifier.
4. Identify a conventional full-wave rectifier and a full-wave bridge rectifier.
5. Select true statements concerning the advantages of a full-wave over a half-wave rectifier.
6. State the formulas for the average and peak DC output voltage of a full-wave rectifier.
7. Determine the DC output voltage of a multiplier circuit.
8. Calculate average DC voltage for half-wave rectifier and full-wave rectifier circuits.
9. Indicate the direction of current flow in a full-wave bridge rectifier and a conventional full-wave rectifier.
10. Demonstrate the ability to:
    a. Construct and test a half-wave rectifier circuit.
    b. Construct and test a full-wave bridge rectifier circuit.
    c. Construct and test a voltage doubler circuit.

RECTIFIERS
UNIT II

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information, assignment, and job sheets.

III. Make transparencies.

IV. Discuss unit and specific objectives.

V. Discuss information and assignment sheets.

VI. Demonstrate and discuss the procedures outlined in the job sheets.

VII. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

   A. Objective sheet

   B. Information sheet

   C. Transparency masters

      1. TM 1--Half-Wave Rectifier Circuits
      2. TM 2--Conventional Full-Wave Rectifier
      3. TM 3--Bridge Rectifier
      4. TM 4--Voltage Doubler Circuit

   D. Assignment sheets

      1. Assignment Sheet #1--Calculate Average DC Voltage for Half-Wave and Full-Wave Rectifier Circuits
      2. Assignment Sheet #2--Indicate the Direction of Current Flow in a Full-Wave Bridge Rectifier and a Conventional Full-Wave Rectifier

   E. Answer to assignment sheets

   F. Job sheets

      1. Job Sheet #1--Construct and Test a Half-Wave Rectifier Circuit
      2. Job Sheet #2--Construct and Test a Full-Wave Bridge Rectifier Circuit

    3. Job Sheet #3--Construct and Test a Voltage Doubler Circuit

  G. Test

  H. Answers to test

II. Reference--Grob, Bernard. *Basic Electronics*. Third Edition. New York: McGraw-Hill Book Company, 1971.

RECTIFIERS
UNIT II

INFORMATION SHEET

I. Terms and definitions

A. Rectifier circuit--A circuit that converts AC voltages to pulsating DC voltages

B. Half-wave rectifier--A circuit that converts AC voltage to pulsating DC voltage and allows DC current to flow only through the load during one-half of each AC input cycle

C. Full-wave rectifier--A circuit that converts AC voltage to pulsating DC voltage and allows current to flow in the same direction through the load for both halves of the input AC voltage cycle

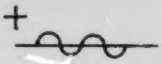
D. Transformer--A device which is used to either step up (increase) or step down (decrease) the AC voltage in a rectifier circuit

E. Bridge rectifier--A type of rectifier circuit that requires four diodes in order to make a full-wave rectifier

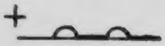
F. Voltage doubler--A rectifier circuit that is used to increase (double) the DC output voltage without using a step up transformer

II. Input and output waveforms for a basic half-wave rectifier circuit (Transparency 1)

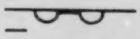
A. Input voltage--



B. Output voltage--



OR



III. Formulas for the average and peak DC output voltage of a half-wave rectifier

A. Vdc = .318 Vpk

B. Vpk = 1.414 Vrms

IV. Full-wave rectifiers (Transparencies 2 and 3)

A. Conventional

B. Full-wave bridge

INFORMATION SHEET

V. Advantages of a full-wave over a half-wave rectifier

   A. More efficient

   B. Less ripple effect

   C. Wider variety of applications

VI. Formulas for the average and peak DC output voltage of a full-wave rectifier

   A. Vdc = .636 Vpeak

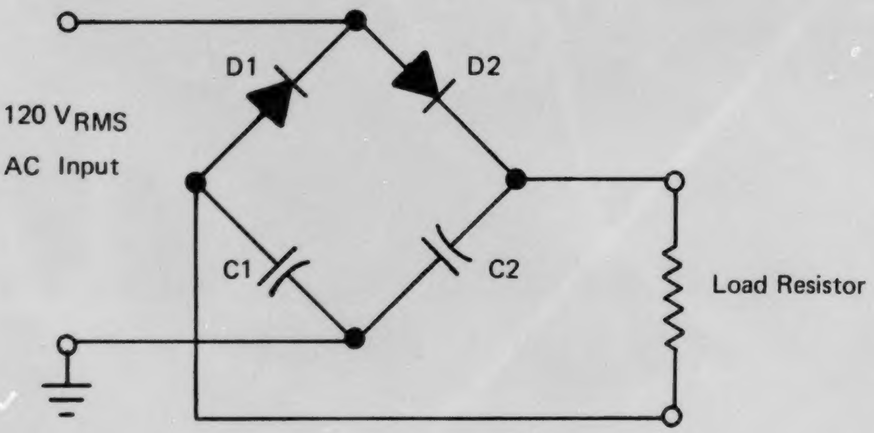
   B. Vpk = 1.414 Vrms

VII. Steps in determining the DC voltage of a multiplier circuit

   A. Determine the voltage input (Transparency 4)

   B. Multiply the peak input voltage times the number of rectifiers

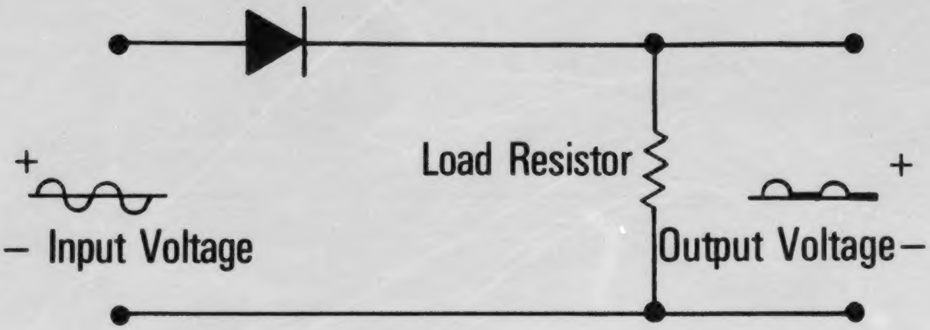
   Example:

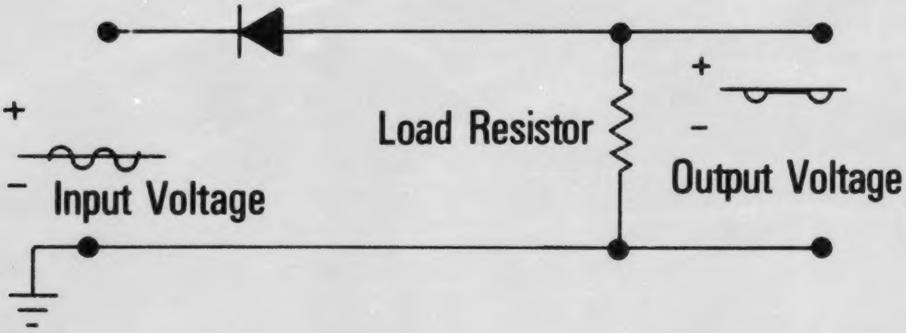


120V AC Input X 2 (rectifiers) = 240V DC output

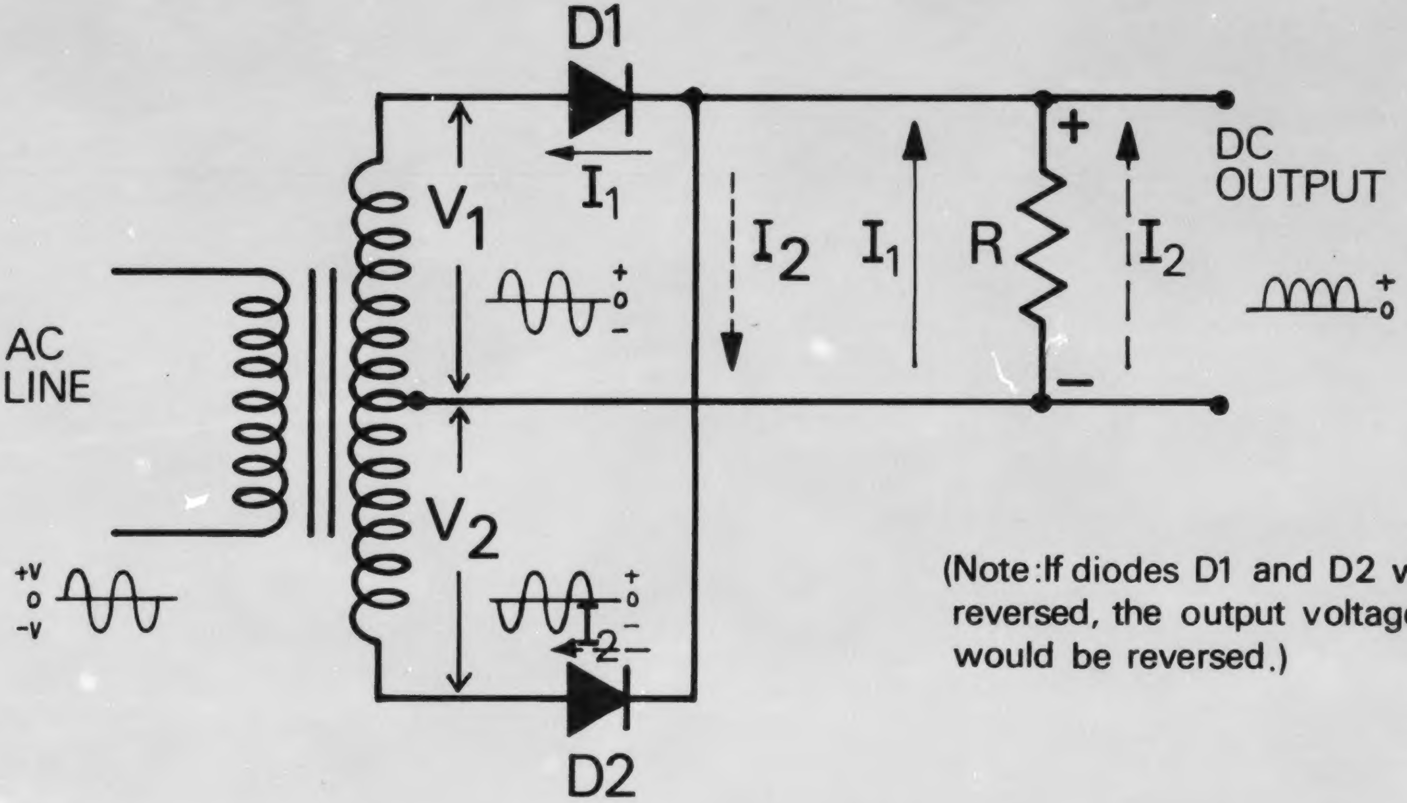
(NOTE: This is an example of a voltage doubler used in a specialized multiplier circuit.)

Half-Wave Rectifier Circuits


+
– Input Voltage
Load Resistor
+
Output Voltage –

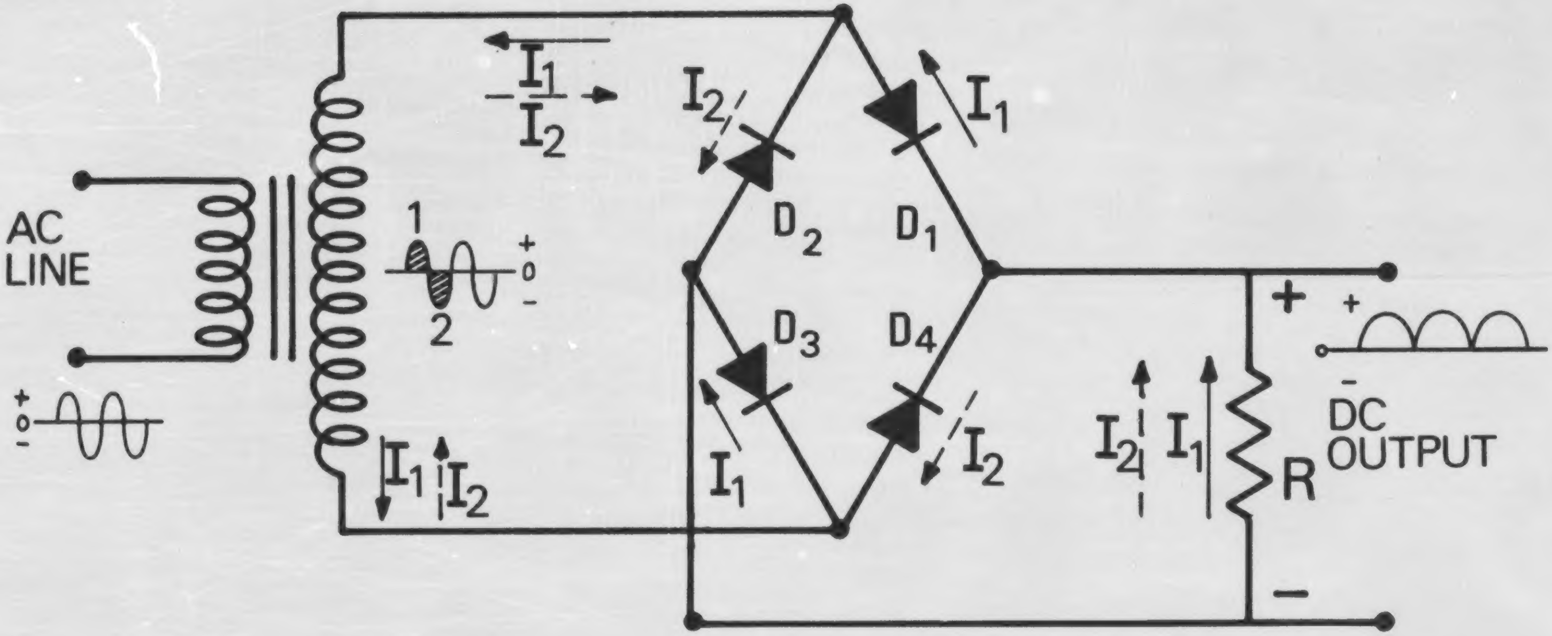

+
– Input Voltage
Load Resistor
+
–
Output Voltage

Conventional Full-Wave Rectifier


D1
I1
V1
I2
I1
R
I2
+
−
DC
OUTPUT
AC
LINE
+V
0
−V
V2
I2
D2
+
0
−

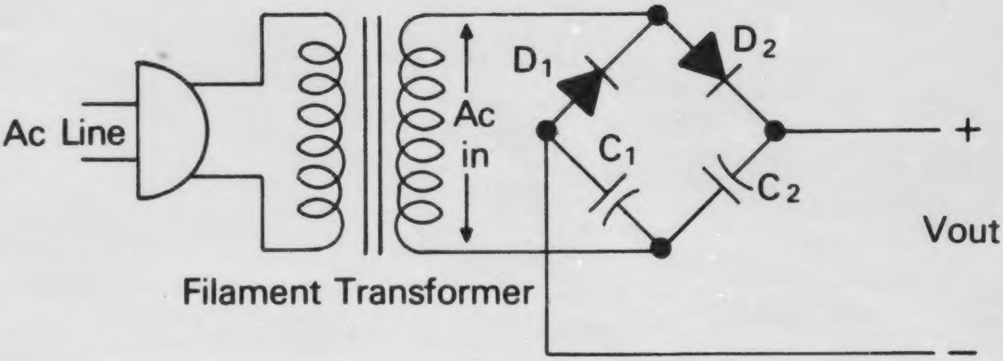
(Note: If diodes D1 and D2 were reversed, the output voltage would be reversed.)

Bridge Rectifier


AC
LINE
I_1
I_2
I_2
I_1
D_2
D_1
D_3
D_4
1
2
+
0
−
I_1
I_2
I_1
I_2
I_2
I_1
R
+
−
DC
OUTPUT

(Note : If each of the diodes were reversed the output would be reversed.)

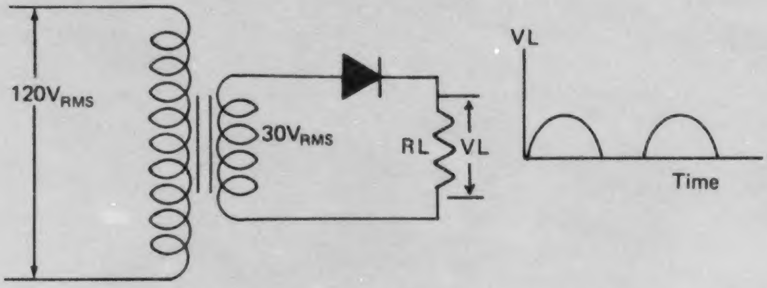
Voltage Doubler Circuit


Ac Line
Ac
in
D1
D2
C1
C2
+
Vout
–
Filament Transformer

RECTIFIERS
UNIT II

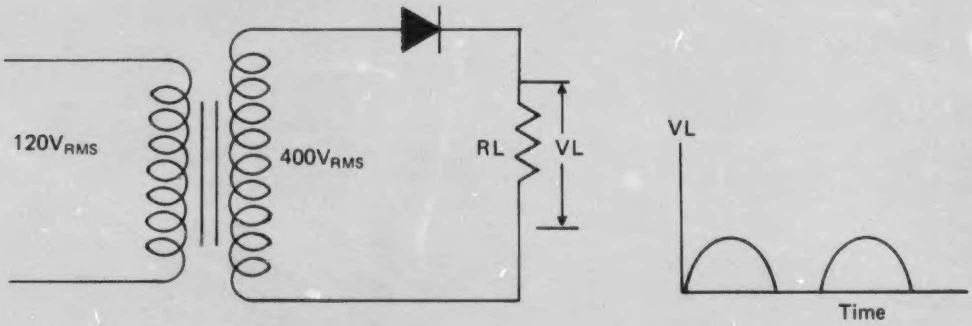
ASSIGNMENT SHEET #1--CALCULATE AVERAGE DC VOLTAGE FOR HALF-WAVE RECTIFIER AND FULL-WAVE RECTIFIER CIRCUITS

1. Calculate the average DC voltage for the following circuit.


$120V_{RMS}$
$30V_{RMS}$
RL
VL
VL
Time

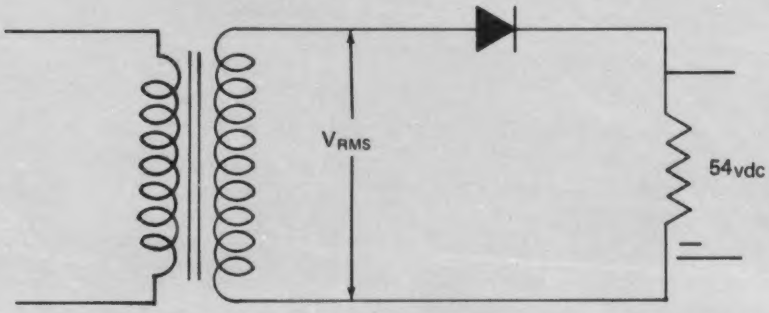
Vdc =

2. Calculate the average DC voltage for the following circuit.


$120V_{RMS}$
$400V_{RMS}$
RL
VL
VL
Time

Vdc =

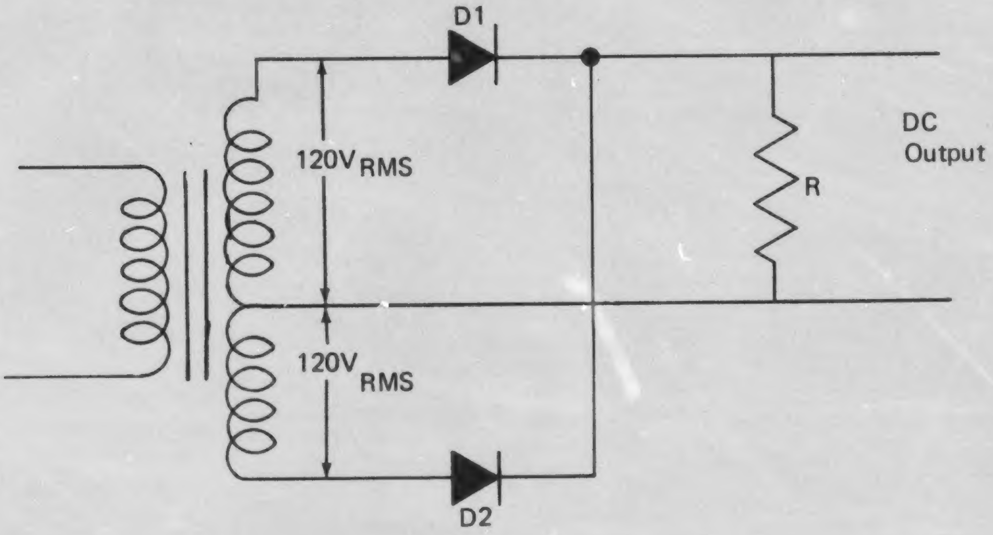
3. Calculate the transformer's secondary rms voltage.



Vrms =

ASSIGNMENT SHEET #1

4. Calculate the average DC voltage for the following circuit.

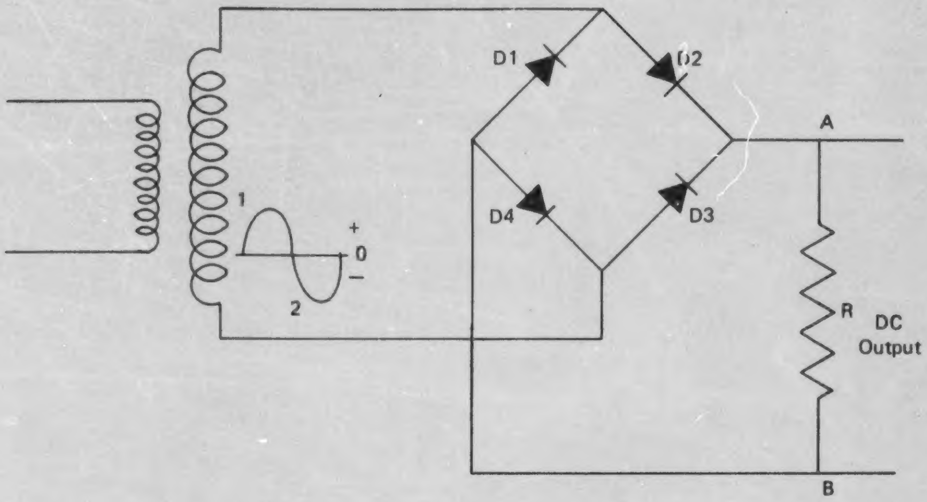

D1
120V$_{RMS}$
120V$_{RMS}$
D2
R
DC
Output

Vdc =

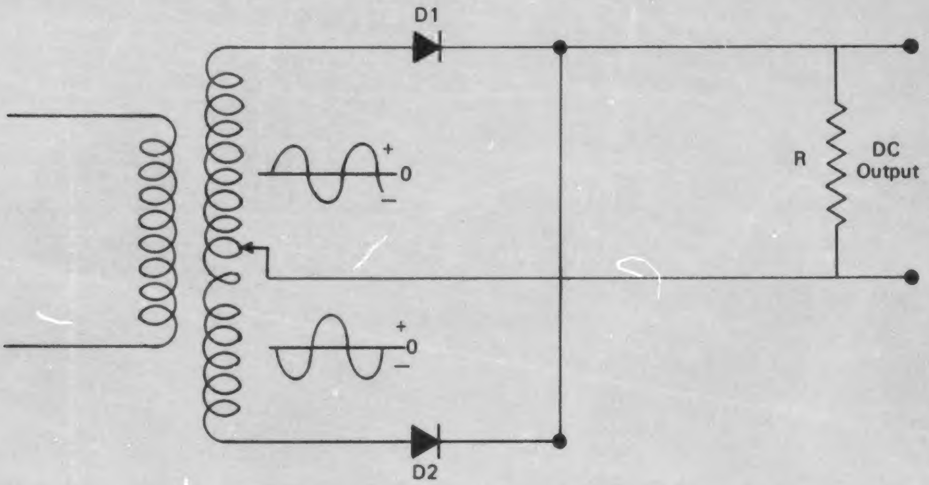
RECTIFIERS
UNIT II

ASSIGNMENT SHEET #2--INDICATE THE DIRECTION OF CURRENT FLOW IN A FULL-WAVE BRIDGE RECTIFIER AND A CONVENTIONAL FULL-WAVE RECTIFIER

1. Trace and label the paths of the current flow through the bridge rectifier circuit and the load for one complete input cycle and label the voltage polarity at points A and B



2. Trace and label the paths of the current flow through a conventional full-wave rectifier circuit for one complete input cycle.



RECTIFIERS
UNIT II

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

1. $V_{L(peak)} = 1.414\ \mathrm{Vrms}$

   $V_{L(peak)} = (1.414)(30) = 42.4\mathrm{V}$

   $\mathrm{Vdc} = 0.318\ V_{L(peak)}$

   $\mathrm{Vdc} = (0.318)\ (42.4) = 13.5\mathrm{V}$

2. $V_{L(peak)} = (1.414)\ (400) = 565\mathrm{V}$

   $\mathrm{Vdc} = (0.318)(565) = 180\mathrm{V}$

3. $V_{L(peak)} = \dfrac{54}{0.318} = 170$

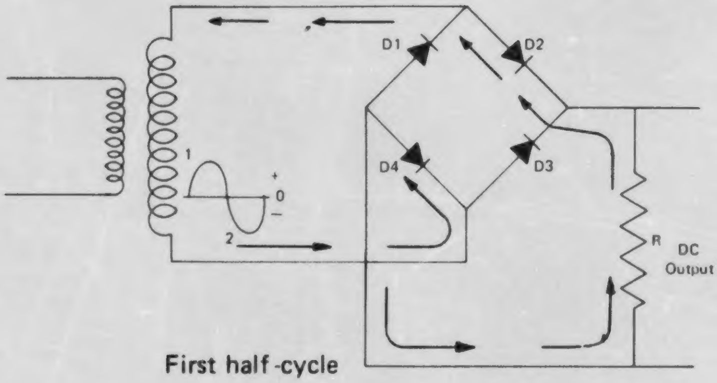
   $V_{rms} = \dfrac{170}{1.414} = 120\mathrm{V}$

4. $\mathrm{Vpeak} = 1.414 \times 120 = 170\mathrm{V}$

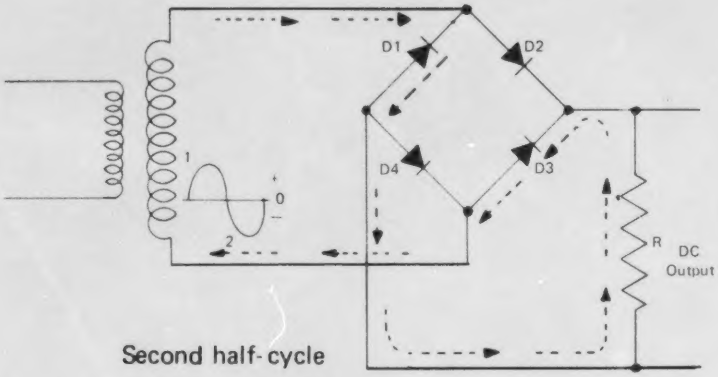
   $\mathrm{Vdc} = (0.636)\ (170) = 108\mathrm{V}$

Assignment Sheet #2

1.

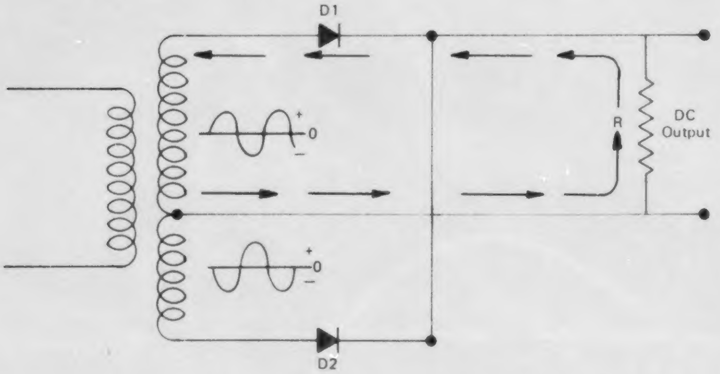


First half-cycle

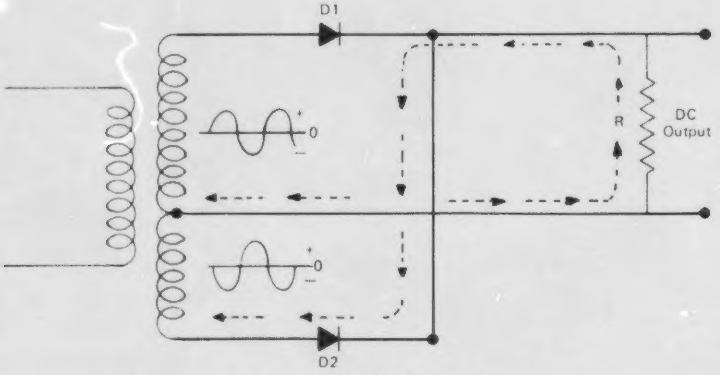

D1
D2
D3
D4
1
2
+
0
−
R
DC
Output

Second half-cycle

2.


D1
D2
+
0
−
R
DC
Output

First half-cycle


D1
D2
+
0
−
R
DC
Output

Second half-cycle

RECTIFIERS
UNIT II

JOB SHEET #1--CONSTRUCT AND TEST A HALF-WAVE RECTIFIER CIRCUIT

I. Tools and equipment

A. Low power filament transformer (120V Primary)

B. Silicon diode, 1N914 or equivalent

C. 2-6800 Ohm, 1/2 Watt resistors

D. Multimeter

E. Oscilloscope

F. Graph paper

II. Procedure

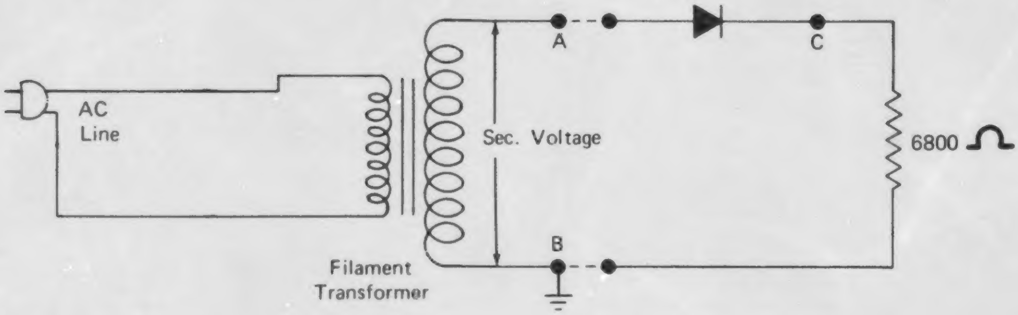
(CAUTION: Dangerous voltage levels are present during this procedure. Check with your instructor regarding safety procedures.)

A. Connect the multimeter (set for AC) to secondary of the filament transformer

B. Plug the filament transformer into the line voltage and measure the secondary voltage at points A and B

C. Turn off the power

D. Connect the following circuit to the secondary of the filament transformer



JOB SHEET #1

E. Turn the power on

F. Measure the voltage between points A and B and record this below as the AC input voltage

G. Measure and record the DC output voltage with the multimeter

H. Observe and make a scale drawing below of the AC input voltage (A to B) and the DC output voltage (C to B)

I. Calculate the average DC output voltage and compare it to the measured DC output voltage

J. Check your calculations and your drawing with your instructor

DATA:

Measured voltage A to B _______ V_{rms}

Measured voltage B to C _______ V_{rms}

Calculated output voltage _______ V_{dc}

RECTIFIERS
UNIT II

JOB SHEET #2--CONSTRUCT AND TEST A FULL-WAVE BRIDGE RECTIFIER CIRCUIT

I. Tools and equipment

A. Auto transformer (0-130V)

B. Power transformer (110-220V CT)

(NOTE: You may use a low power filament transformer. See Job Sheet #1.)

C. Four silicon diodes IN914 or equivalent

D. 1-10k, 1W resistor

E. Multimeter

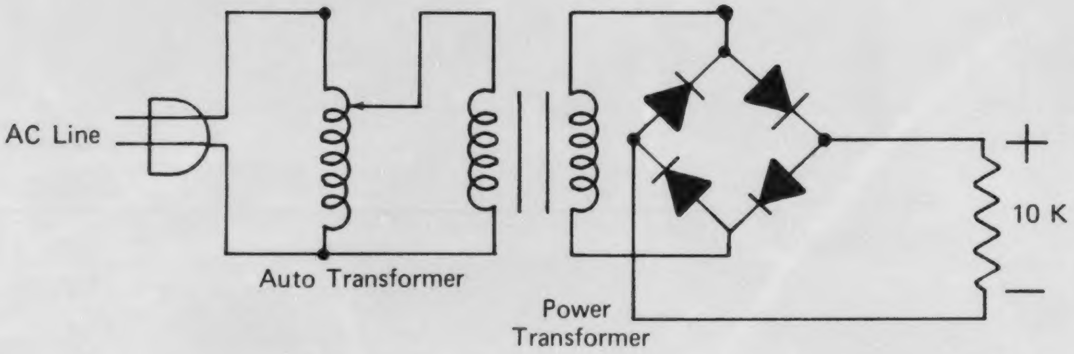
F. Oscilloscope

G. Graph paper

II. Procedure

(CAUTION: Dangerous voltage levels are present during this procedure. Avoid shock hazards.)

A. Construct the circuit shown below but do not connect power at this time



B. Have your instructor check your circuit

C. Connect the multimeter across the secondary of the power transformer

D. Connect the auto transformer to the AC line and adjust for a reading of 10V on the multimeter

JOB SHEET #2

E. Read and record the DC voltage across the 10K load resistor

F. Connect an oscilloscope across the filament transformer secondary and observe and sketch the waveform

G. Connect an oscilloscope across the 10K load resistor and observe and sketch the waveform

H. Calculate the average DC output voltage and compare with the measured DC output voltage

I. Check your calculations and your sketch with your instructor

DATA:

Measured voltage A to B ______ V_{rms}

Measured voltage B to C ______ V_{dc}

Calculated output voltage ______ V_{dc}

RECTIFIERS
UNIT II

JOB SHEET #3--CONSTRUCT AND TEST A VOLTAGE DOUBLER CIRCUIT

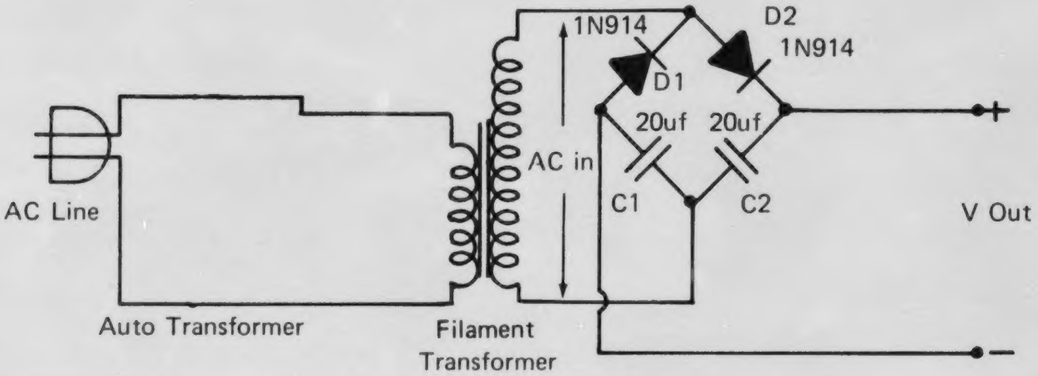
I. Tools and equipment

- A. Low power filament transformer (120V Primary)
- B. 2 silicon diodes, 1N914 or equivalent
- C. 2-20 μF capacitors, 450v
- D. Multimeter
- E. Oscilloscope

II. Procedure

(CAUTION: Dangerous voltage levels are present during this procedure. Avoid shock hazards.)

A. Connect the following circuit but do not connect the filament transformer to the AC line


1N914
D2
1N914
D1
20uf
20uf
AC in
C1
C2
AC Line
V Out
+
−
Auto Transformer
Filament Transformer

B. Have your instructor check your wiring, then plug in the filament transformer

C. Measure and record the voltage across C_1, C_2, the output, and the secondary winding of the filament transformer

D. Using an oscilloscope, observe and measure the input and output voltages of the rectifier circuit and sketch the waveforms

E. Check your findings with your instructor

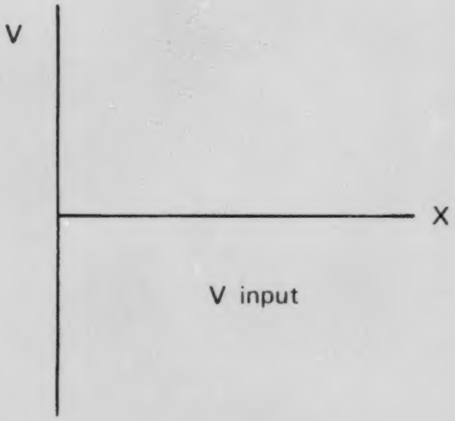
JOB SHEET #3

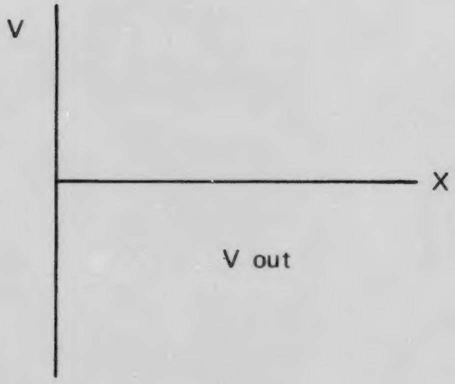
DATA:

V_{c1} = ______

V_{c2} = ______

$V_{secondary}$ = ______





RECTIFIERS
UNIT II

NAME ______________________________

TEST

1. Match the terms on the right with their correct definitions.

   _____a. A type of rectifier circuit that requires four diodes in order to make a full-wave rectifier

   _____b. A circuit that converts AC voltages to pulsating DC voltages

   _____c. A rectifier circuit that is used to increase the DC output voltage without using a set-up transformer

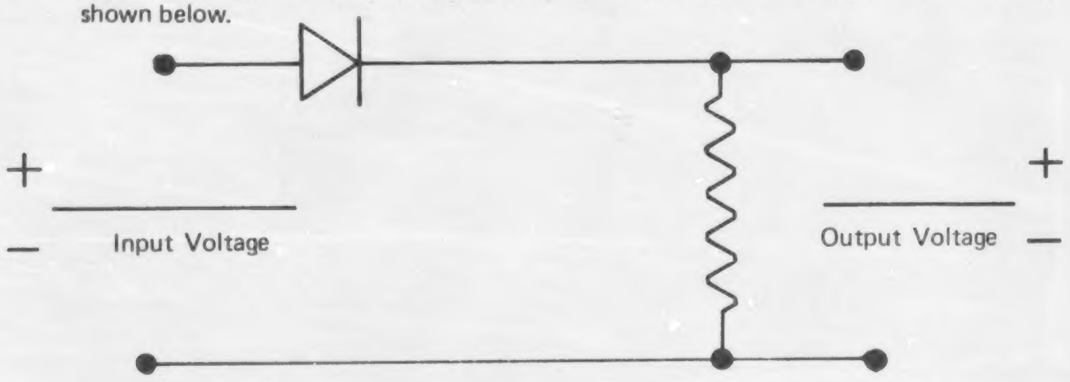
   _____d. A circuit that converts AC voltage to pulsating DC voltage and allows DC current to flow only through the load during one-half of each AC input cycle

   _____e. A device which is used to either step up or step down the AC voltage in a rectifier circuit

   _____f. A circuit that converts AC voltage to pulsating DC voltage and allows current to flow in the same direction through the load for both halves of the input AC voltage cycle

   1. Rectifier circuit
   2. Half-wave rectifier
   3. Full-wave rectifier
   4. Transformer
   5. Bridge rectifier
   6. Voltage doubler

2. Sketch the input and output waveform symbols for the basic half-wave rectifier circuit shown below.

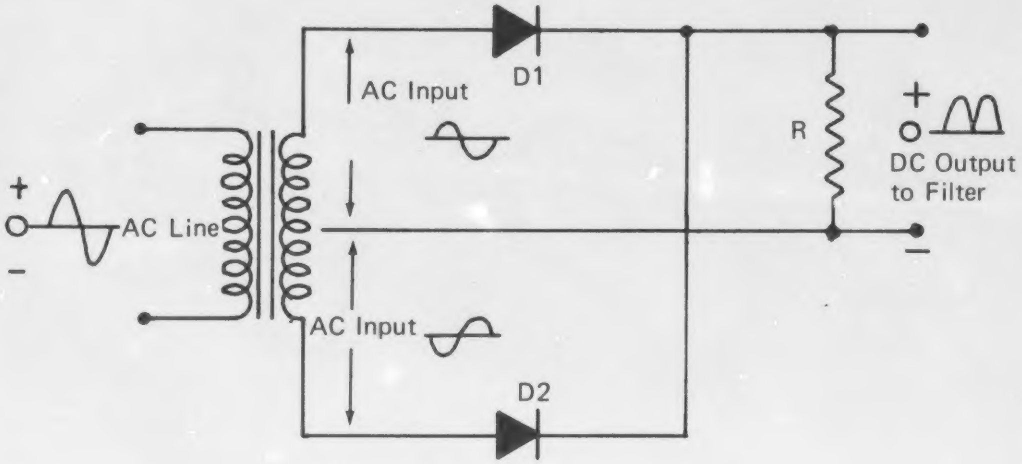


3. State the formula for the average and peak DC output voltage of a half-wave rectifier.

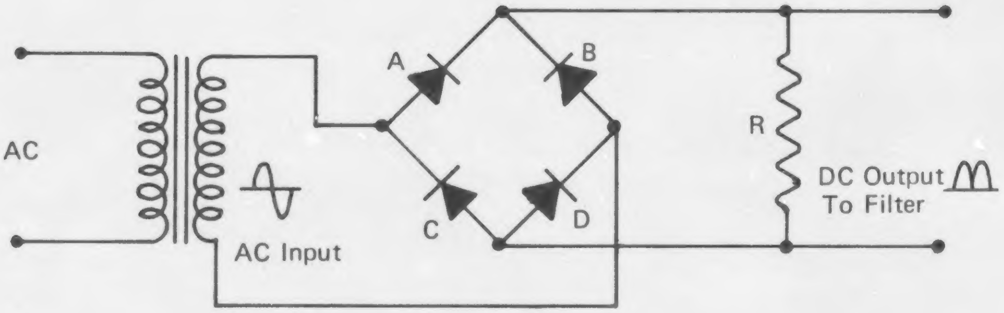
a. ______________________________

b. ______________________________

4. Identify the conventional full-wave rectifier and the full-wave bridge rectifier in the following illustrations.


D1
AC Input
R
+
DC Output
to Filter
+
AC Line
–
AC Input
D2
–

a. ______________________________


A
B
AC
R
DC Output
To Filter
C
D
AC Input

b. ______________________________

5. Select true statements concerning the advantages of a full-wave over a half-wave rectifier by placing an "X" in the appropriate blanks.

   _____a. Less efficient

   _____b. Less ripple effect

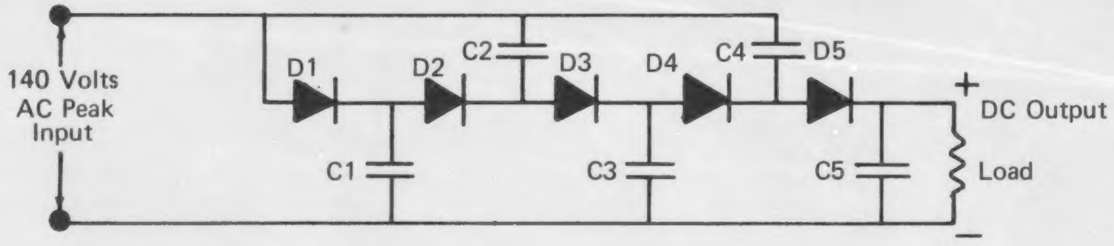
   _____c. Wider variety of applications

6. State the formulas for the average and peak DC output voltage of a full-wave rectifier.

   a. ______________________________

   b. ______________________________

7. Determine the DC ouput voltage of the multiplier circuit given below.



V out = ______________________

8. Calculate average DC voltage for half-wave rectifier and full-wave rectifier circuits.

9. Indicate the direction of current flow in a full-wave bridge rectifier and a conventional full-wave rectifier.

10. Demonstrate the ability to:

    a. Construct and test a half-wave rectifier circuit.

    b. Construct and test a full-wave bridge rectifier circuit.

    c. Construct and test a voltage doubler circuit.

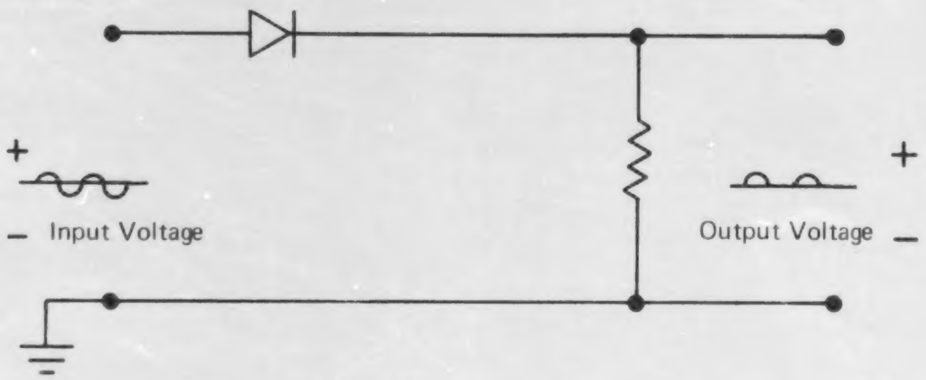
    (NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

RECTIFIERS
UNIT II

ANSWERS TO TEST

1. a.	5	d.	2
b.	1	e.	4
c.	6	f.	3

2.



3. a. Vdc = .318 Vpk
   b. Vpk = 1.414 Vrms

4. a. Conventional full-wave rectifier
   b. Full-wave bridge rectifier

5. b, c

6. a. Vdc = .636 Vpeak
   b. Vpk = 1.414 Vrms

7. V out = (140)(5) = 700

8. Evaluated to the satisfaction of the instructor

9. Evaluated to the satisfaction of the instructor

10. Performance skills evaluated to the satisfaction of the instructor

FILTERS
UNIT III

UNIT OBJECTIVES

After completion of this unit, the student should be able to identify the three most common filter configurations and calculate the ripple factor of a filtered power supply. This knowledge will be evidenced by correctly performing the procedures outlined in the assignment and job sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to filters with their correct definitions.
2. Select a statement describing the purpose of filters.
3. Sketch the voltage waveshapes at the output of the transformer, rectifier, and filter for a half-wave power supply.
4. Distinguish between the basic filter types.
5. Identify the three basic filter configurations.
6. State the function of and the formula for ripple factor.
7. Calculate ripple factors and percent regulation.
8. Demonstrate the ability to:
    a. Construct and test a capacitor filter circuit.
    b. Construct and test a Pi-section filter circuit.

FILTERS
UNIT III

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information, assignment, and job sheets.

III. Make transparency.

IV. Discuss unit and specific objectives.

V. Discuss information and assignment sheets.

VI. Demonstrate and discuss the procedures outlined in the job sheets.

VII. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

   A. Objective sheet

   B. Information sheet

   C. Transparency Master 1--Basic Filter Configurations

   D. Assignment Sheet #1--Calculate Ripple Factors and Percent Regulation

   E. Answers to assignment sheet

   F. Job sheets

      1. Job Sheet #1--Construct and Test a Capacitor Filter Circuit

      2. Job Sheet #2--Construct and Test a Pi-Section Filter Circuit

   G. Test

   H. Answers to test

II. Reference--Grob, Bernard. *Basic Electronics*. Third Edition. New York: McGraw-Hill Book Company, 1971.

FILTERS
UNIT III

INFORMATION SHEET

I. Terms and definitions

A. Ripple--Variations in the DC voltage

B. Filter--A device used to eliminate or minimize ripple

C. Bleeder resistor--A resistor placed in parallel with a capacitor in order to provide a discharge path for the capacitor when the power supply is turned off

D. Power supply voltage regulation--The ability of a power supply to maintain a constant output voltage under varying loads

E. Percent regulation--Comparison of the no-load voltage to the full-load voltage expressed as a percentage of the full-load voltage

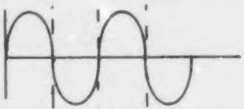
(NOTE: $\% \text{ Reg} = \dfrac{\text{Vout}_{\text{no-load}} - \text{Vout}_{\text{full-load}}}{\text{Vout}_{\text{full-load}}} \times 100$)

F. DC power supply--A basic electronic system generally consisting of a transformer, a rectifier, and a filter to convert AC voltage to DC voltage

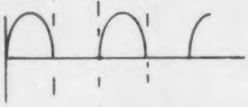
II. Purpose of filters--Filters help to provide a smooth, nonfluctuating DC output voltage from a rectifier circuit

III. Output waveshapes for a half-wave power supply

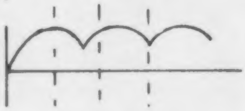
A. Transformer output--



B. Rectifier output--



C. Filter output--



(NOTE: See Transparency 1 for location of output waveshapes A, B, and C.)

IV. Basic filter types

A. Capacitor filter

1. Simplest filter
2. Most economical
3. Used where load does not require an extremely smooth DC voltage

INFORMATION SHEET

B. Pi-section filter

  1. Requires two capacitors and an inductor

     (NOTE: The inductor is sometimes replaced by a resistor.)

  2. Used when a smooth voltage with relatively low current is required

  3. Also called capacitance-input filter

C. L-section filter

  1. Used for high current applications

  2. Requires an inductor or "choke" in series with a capacitor

V. Basic filter configurations (Transparency 1)

  A. Capacitor filter

  B. Pi-section filter

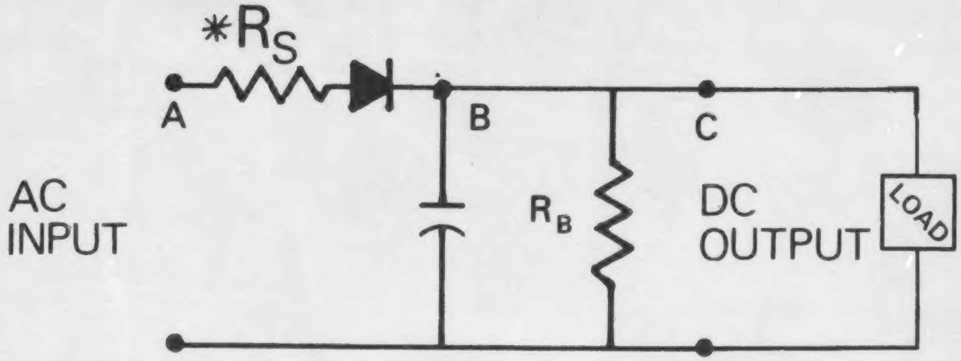
  C. Two L-section filter (choke input)

VI. Function of and the formula for ripple factor

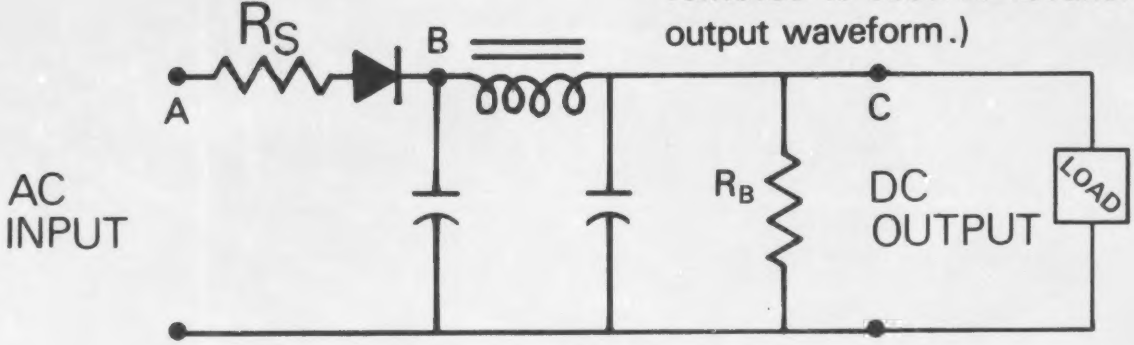
  A. Expresses the effectiveness of filtering

  B. $r = \frac{\text{rms value of ripple output}}{\text{DC output voltage}}$

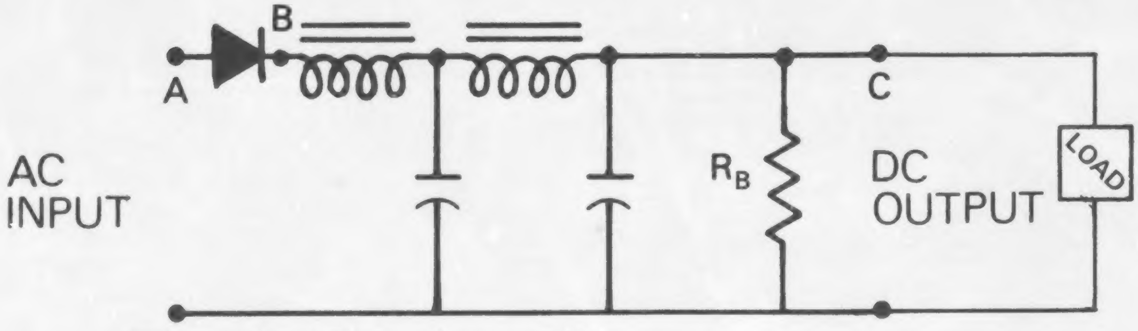
Basic Filter Configurations


*R_S
A
B
C
AC INPUT
R_B
DC OUTPUT
LOAD

Capacitor Filter (NOTE- Capacitor must be removed to observe rectifier output waveform.)


R_S
B
A
C
AC INPUT
R_B
DC OUTPUT
LOAD

PI-Section Filter


B
A
C
AC INPUT
R_B
DC OUTPUT
LOAD

Two L-Section Filter

* (NOTE- R_S in series with diode limits initial surge of current due to capacitor and is called a surge resistor.)

FILTERS
UNIT III

ASSIGNMENT SHEET #1--CALCULATE RIPPLE FACTORS AND PERCENT REGULATION

1. A power supply has DC output voltage of 30 volts and a ripple of 10 Vrms. The ripple factor is ________________________________

2. A power supply has DC output voltage of 15 volts and a ripple of .050 volts rms. The ripple factor is ________________________________

3. Which one of the above power supplies has the most effective filtering and why?

4. A power supply has an output voltage at no-load of $24V_{DC}$ and an output voltage of $22\ V_{DC}$ at full-load. The percent regulation is ________________________

FILTERS
UNIT III

ANSWERS TO ASSIGNMENT SHEET #1

1. $r = 0.33$
2. $r = 0.0033$
3. #2, smaller ripple factor
4. 8.3%

FILTERS
UNIT III

JOB SHEET #1--CONSTRUCT AND TEST A CAPACITOR FILTER CIRCUIT

I. Tools and equipment

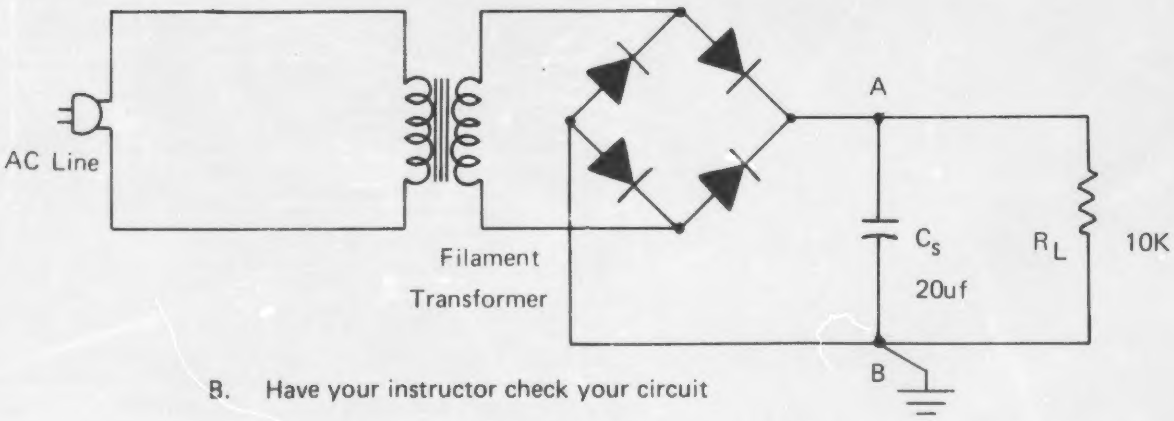
- A. Low power filament transformer (120V primary)
- B. 4-silicon diodes 1N914 or equivalent
- C. 1-10K, 1/2 watt resistor, 1-1K, 1/2 watt resistor, 2-20 μf capacitor, 25 WV_{dc} or greater
- D. Multimeter
- E. Oscilloscope
- F. Graph paper

II. Procedure

(CAUTION: Dangerous voltage levels are present during this procedure. Avoid shock hazards.)

- A. Construct the circuit shown below but do not connect power at this time

  (NOTE: Do not connect the capacitor at point A & B at this time.)



- B. Have your instructor check your circuit
- C. Connect the multimeter across the secondary of the filament transformer and record the voltage
- D. Read and record the DC voltage across the load resistor

JOB SHEET #1

E. Connect an oscilloscope across the load resistor, observe and sketch the wave form

F. Turn off the power

G. Connect the 20 μf capacitor at points A and B

H. Turn the power on

I. Repeat steps D through F

J. Replace the 10K load resistor with the 1K load resistor and repeat steps D through I

K. Compare the wave shapes and DC voltage levels of the filter and a 10K load resistor with the filter and a 1K load resistor

L. Using the output voltage measured with the 10K load resistor as no-load voltage and the output voltage measured with the 1K resistor as full-load, compute percent voltage regulation on the table below

DATA	$V_{sec.}$	V_{10K}	V_{1K}	% Reg
No filter				
With filter				

M. Check your calculations and sketches with your instructor

FILTERS
UNIT III

JOB SHEET #2--CONSTRUCT AND TEST A PI-SECTION FILTER CIRCUIT

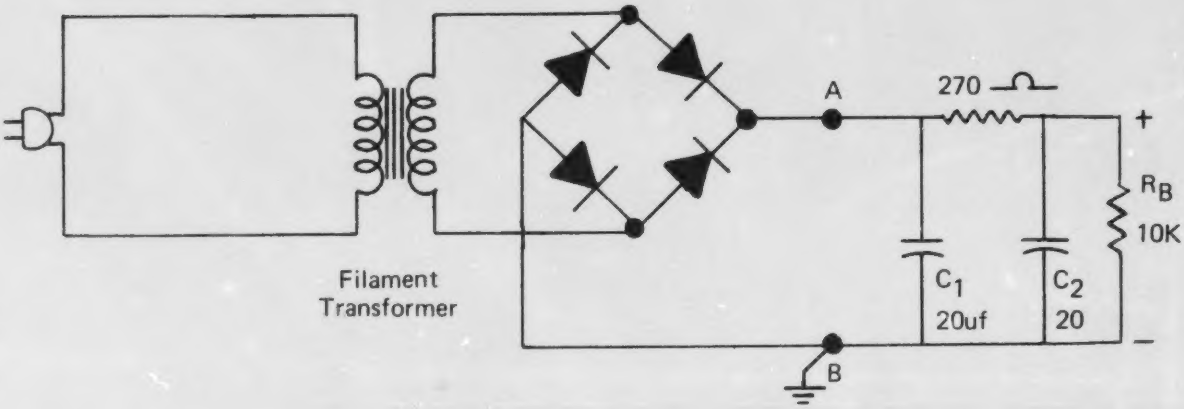
I. Tools and equipment

- A. Low power filament transformer (120V primary)
- B. 4-silicon diodes 1N914 or equivalent
- C. 1-10K, 1/2 watt resistor
- D. 1-1K, 1/2 watt resistor
- E. 2-20 μf capacitors 25WV$_{dc}$ or greater
- F. Multimeter
- G. Oscilloscope
- H. Graph paper
- I. 1-270 ohm resistor

II. Procedure

A. Connect the circuit shown below but do not apply power at this time

(NOTE: Do not connect the Pi-section filter network at point A and B at this time.)



B. Have your instructor check your circuit

C. Connect the multimeter across the secondary of the filament transformer

JOB SHEET #2

D. Read and record the DC voltage across the load resistor

E. Connect an oscilloscope across the load resistor, observe and sketch the wave form

F. Turn off the power

G. Connect the Pi-section at points A and B

H. Turn on the power

I. Repeat steps D through F

J. Replace the 10K load resistor with a 1K load resistor and repeat steps D through I

K. Compare the wave shapes and DC voltage levels of the Pi-section filter and the 10K load resistor with the Pi-section filter and the 1K resistor

M. Using the output voltage measured with the 10K load resistor as no-load voltage and the output voltage measured with the 1K resistor as full-load, compute percent voltage regulation on the table below

DATA	V_{10K}	V_{1K}	% Reg.
No filter			
With filter			

N. Check your calculations and your sketches with your instructor

FILTERS
UNIT III

NAME ____________________

TEST

1. Match the terms on the right with their correct definitions.

______a. A basic electronic system generally consistting of a transformer, a rectifier, and a filter to convert AC voltage to DC voltage

______b. Variations in the DC voltage

______c. Comparison of the no-load voltage to the full-load voltage expressed as a percentage of the full-load voltage

______d. A device used to eliminate or minimize ripple

______e. The ability of a power supply to maintain a constant output voltage under varying loads

______f. A resistor placed in parallel with a capacitor in order to provide a discharge path for the capacitor when the power supply is turned off

1. Filter
2. Percent regulation
3. Ripple
4. DC power supply
5. Bleeder resistor
6. Power supply voltage regulation

2. Select the statement which describes the purpose of a filter by placing an "X" in the appropriate blank.

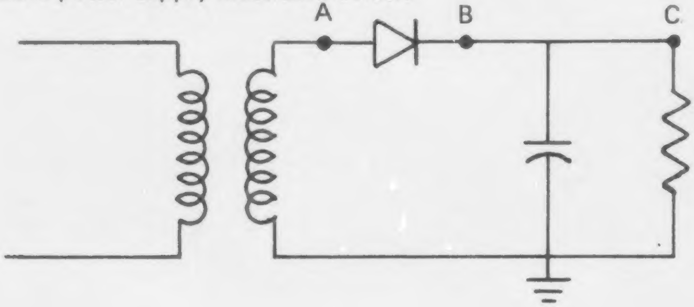
______a. To convert AC voltage to DC voltage

______b. To provide automatic voltage regulation for a power supply

______c. Help to provide a smooth, nonfluctuating DC output voltage from a rectifier circuit

______d. To step up the DC power supply output voltage

3. Sketch the voltage waveshapes at the output of the transformer, rectifier, and filter for the half-wave power supply illustrated below.



a. Transformer output--

b. Rectifier output--

c. Filter output--

4. Distinguish between the basic filter types by placing a "C" next to descriptions of capacitor filters, a "P" next to descriptions of Pi-section filters, and an "L" next to descriptions of L-section filters.

_____a. Requires two capacitors and an inductor

_____b. Used for high current applications

_____c. Most economical

_____d. Also called capacitance-input filter

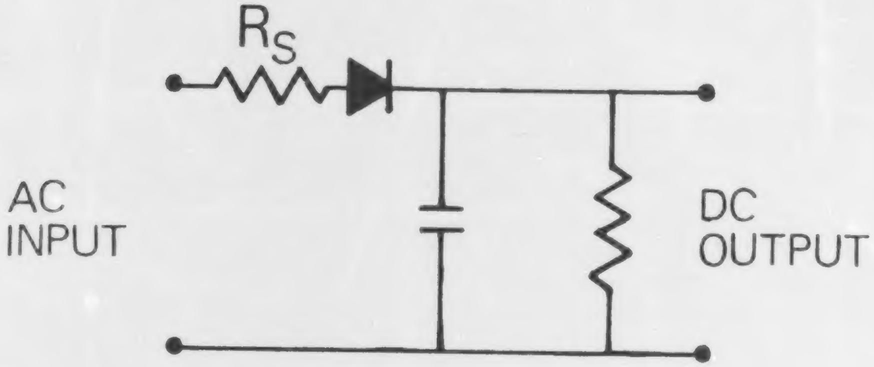
_____e. Used when a smooth voltage with relatively low current is required

_____f. Simplest filter

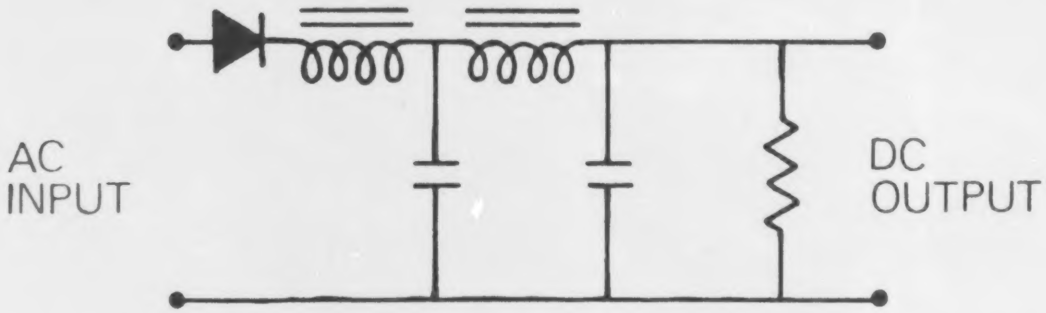
_____g. Used where load does not require an extremely smooth DC voltage

_____h. Requires an inductor or "choke" in series with a capacitor

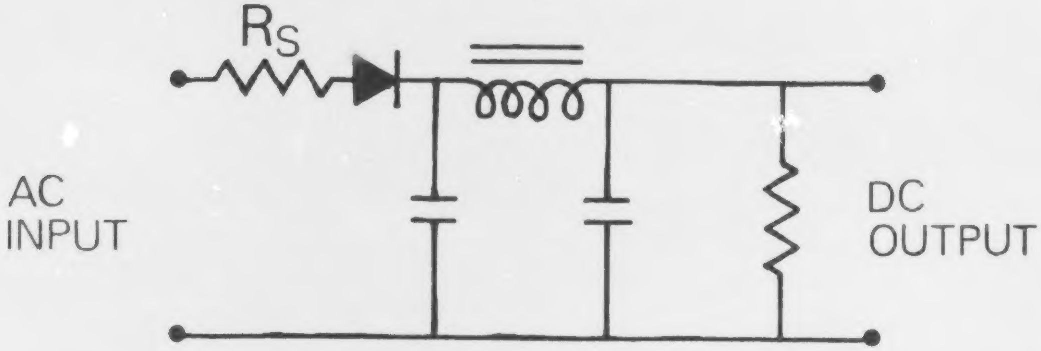
5. Identify the three basic filter configurations shown below.


R_S
AC INPUT
DC OUTPUT

a. ____________ Filter


AC INPUT
DC OUTPUT

b. ____________ Filter


R_S
AC INPUT
DC OUTPUT

c. ____________ Filter

6. State the function of and the formula for ripple factor.

   a. ______________________________

   b. ______________________________

7. Calculate ripple factors and percent regulation.

8. Demonstrate the ability to:

   a. Construct and test a capacitor filter circuit.

   b. Construct and test a Pi-section filter circuit.

   (NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

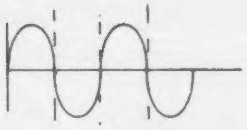
FILTERS
UNIT III

ANSWERS TO TEST

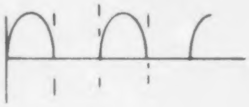
1. a. 4
   b. 3
   c. 2
   d. 1
   e. 6
   f. 5

2. c

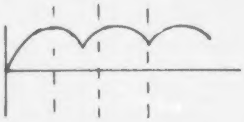
3. a. Transformer output--



   b. Rectifier output--



   c. Filter output--



4. a. P
   b. L
   c. C
   d. P
   e. P
   f. C
   g. C
   h. L

5. a. Capacitor filter
   b. Two L-section filter
   c. Pi-section filter

6. a. Expresses the effectiveness of filtering

   b. $r = \frac{\text{rms value of ripple output}}{\text{DC output voltage}}$

7. Evaluated to the satisfaction of the instructor

8. Performance skills evaluated to the satisfaction of the instructor

SPECIAL SEMICONDUCTOR DIODES
UNIT IV

UNIT OBJECTIVE

After completion of this unit, the student should be able to list applications of special semiconductor diodes, construct the volt-amp characteristic curves for a zener diode, and construct and test a zener diode voltage regulator. This knowledge will be evidenced by correctly performing the procedures outlined in the job sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to special semiconductor diodes with their correct definitions.
2. Select the schematic symbol for a zener diode.
3. Identify the operating point, the zener voltage, the forward-bias region, the zener current, and the reverse-bias region of a zener diode.
4. List the alternate names for zener diodes.
5. Select applications of zener diodes.
6. Select the schematic symbol for a tunnel diode.
7. Identify the negative resistance region, peak point, valley point, and the forward point of a tunnel diode.
8. Select applications of tunnel diodes.
9. Select the schematic symbol for a varactor diode.
10. Complete statements concerning bias voltage and barrier capacitance in varactor diodes.
11. List alternate names for varactor diodes.
12. Select applications of varactor diodes.
13. Select the schematic symbol for a light-emitting diode.
14. Complete statements concerning instantaneous-forward current versus light output in light-emitting diodes.
15. Select applications of light-emitting diodes.

16. Select the schematic sy[illegible]r a photo diode.

17. Complete statements concerning light-input intensity versus current in photo diodes.

18. List three applications of the photo diode.

19. Demonstrate the ability to:

    a. Construct a volt/ampere characteristic curve for a zener diode.

    b. Construct and test a zener diode voltage regulator.

SPECIAL SEMICONDUCTOR DIODES
UNIT IV

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information and job sheets.

III. Make transparencies.

IV. Discuss unit and specific objectives.

V. Discuss information sheet.

VI. Demonstrate and discuss the procedures outlined in the job sheets.

VII. Show various types of transistors.

VIII. Give test.

INSTRUCTIONAL MATERIALS

I. Include in this unit:

- A. Objective sheet
- B. Information sheet
- C. Transparency masters
    - 1. TM 1--Zener Diode Characteristics and Schematic Symbol
    - 2. TM 2--Tunnel Diode Characteristics and Schematic Symbol
- D. Job sheets
    - 1. Job Sheet #1--Construct a Volt/Ampere Characteristic Curve for a Zener Diode
    - 2. Job Sheet #2--Construct and Test a Zener Diode Voltage Regulator
- E. Test
- F. Answers to test

II. Reference--Grob, Bernard. *Basic Electronics*. New York: McGraw-Hill Book Company, 1971.

SPECIAL SEMICONDUCTOR DIODES
UNIT IV

INFORMATION SHEET

I. Terms and definitions

   A. Zener diode--A silicon diode that is designed to operate at a specific reverse-breakdown voltage

   B. Tunnel diode--A diode that has a negative resistance characteristic and can be used as amplifiers, an oscillator, and an extremely fast switching device

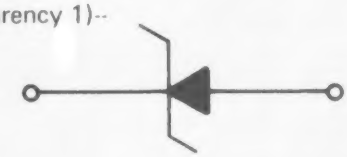
   C. Varactor diode--A diode which serves as a voltage-sensitive capacitor

   D. Light-emitting diode (LED)--A diode specially doped to emit light when forward biased

   E. Photo diode--A diode made from photo-sensitive material; the device's resistance decreases with increased light

   F. Hot-carrier diode--A special diode which uses a metal-to-semiconductor junction and is used for high-frequency rectification

II. Zener diode's schematic symbol (Transparency 1)--



III. Zener diode's volt/ampere characteristic curve (Transparency 1)

   A. Operating point

   B. Zener voltage

   C. Zener current

   D. Forward-bias region

   E. Reverse-bias region

IV. Alternate names for zener diodes

   A. Reference diode

   B. Breakdown diode

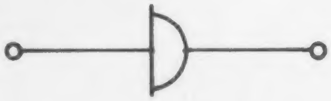
V. Zener diode applications

   A. Voltage regulator

   B. Reference element

INFORMATION SHEET

VI. Schematic symbol for a tunnel diode (Transparency 2)--



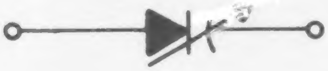
VII. Tunnel diode's volt/ampere characteristic curve (Transparency 2)

- A. Negative resistance region
- B. Peak point
- C. Valley point
- D. Forward point

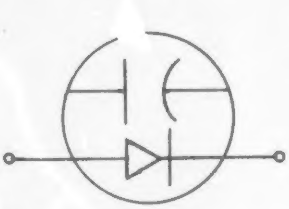
VIII. Applications of tunnel diodes

- A. Amplifiers
- B. Oscillators
- C. Switches
- D. Multivibrators

IX. Schematic symbol for a varactor diode--



OR



X. Bias voltage and barrier capacitance in varactor diodes

- A. The larger the reverse bias, the smaller the barrier capacitance
- B. The larger the foward bias, the larger the barrier capacitance

XI. Alternate names for varactor diodes

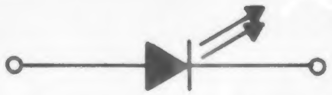
- A. Varicaps
- B. Voltacaps

XII. Applications of varactor diodes

- A. Automatic frequency controls
- B. Variable RC and LC filters

INFORMATION SHEET

XIII. Schematic symbol for a light-emitting diode (LED)--



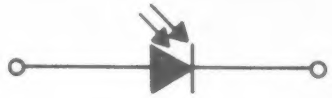
XIV. Instantaneous-forward current versus light output in light-emitting diodes

- A. Light output increases with forward current
- B. There is no light output when LED is reverse biased

XV. Applications of light-emitting diodes

- A. Electroluminescent displays
- B. Logic-level indicators

XVI. Schematic symbol for a photo diode--



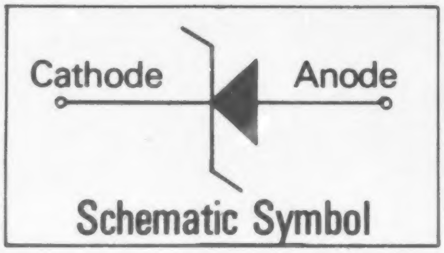
XVII. Light-input intensity versus current in photo diodes

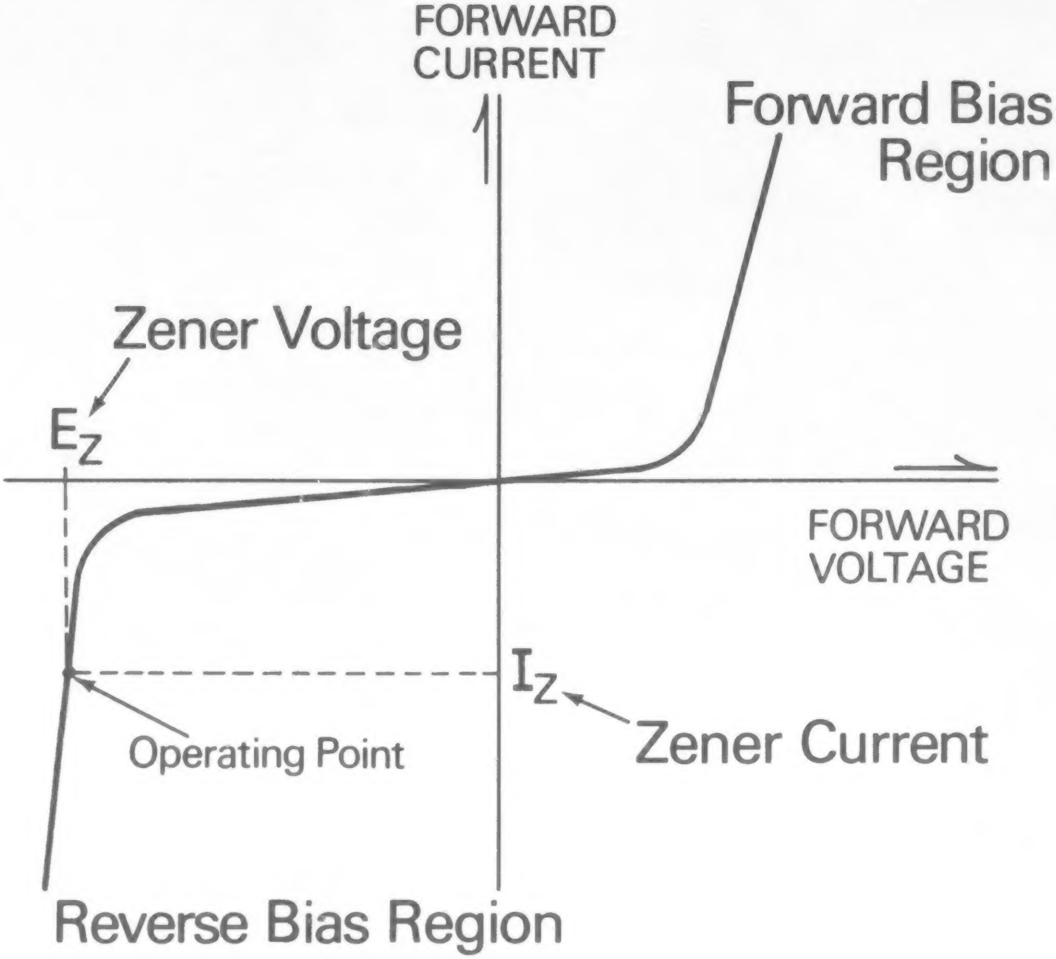
- A. An increase in input-light intensity increases diode current
- B. For a given light-input intensity the diode current is approximately constant for increased reverse-bias voltage

XVIII. Applications of the photo diode

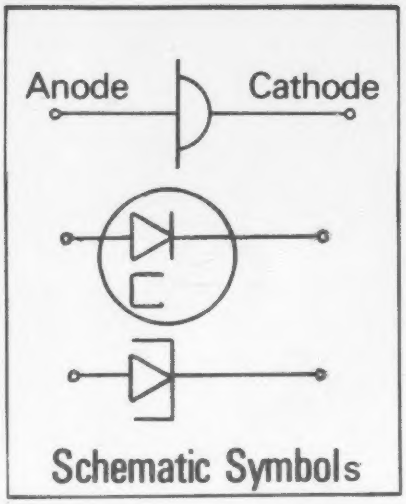
- A. Light-detection systems
- B. High speed card and tape readers
- C. Production line counting of objects which interrupt a light beam

Zener Diode Characteristics and Schematic Symbol

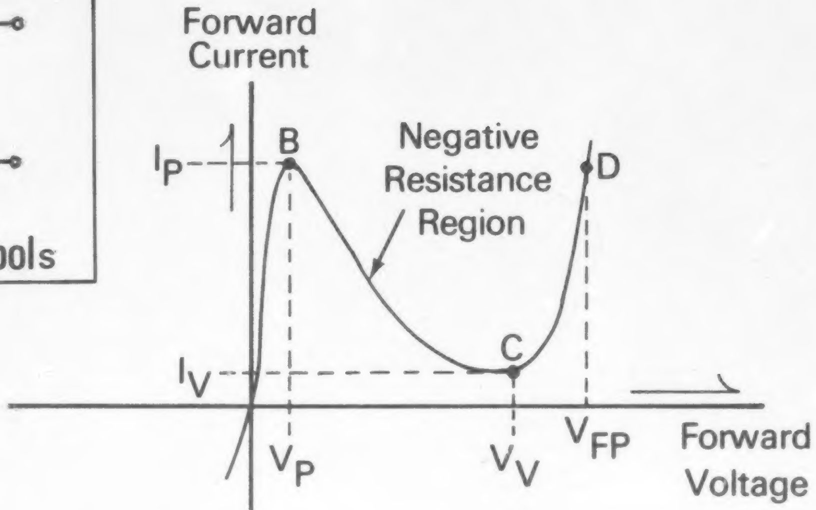

Cathode
Anode
Schematic Symbol



Tunnel Diode Characteristics and Schematic Symbol



Schematic Symbols



B — I_P - Peak-Point Current
B — V_P - Peak-Point Voltage
C — I_V - Valley- Point Current
C — V_V - Valley-Point Voltage
D — V_{FP} - Forward-Point Voltage

Note:
Negative Resistance Region Exists Between Points B and C

SPECIAL SEMICONDUCTOR DIODES
UNIT IV

JOB SHEET #1--CONSTRUCT A VOLT/AMPERE CHARACTERISTIC CURVE FOR A ZENER DIODE

I. Tools and equipment

  A. Power supply (0-15V)

  B. Voltmeter

  C. Milliammeter

  D. 1-1K ohm resistor, 1/2 watt

  E. 1-N4739 zener diode or equivalent

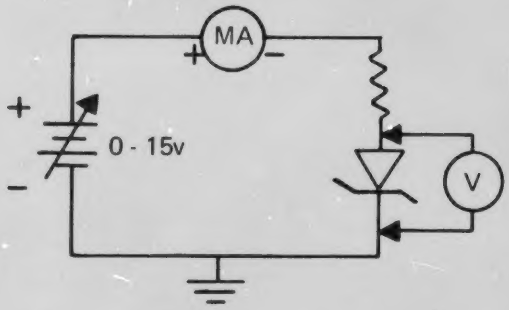
  F. Graph paper

II. Procedure

  A. Set the power supply for 0 volts output

  B. Connect the following circuit

  (NOTE: The zener diode is forward biased.)



  C. Adjust the power supply for 1 volt output

  D. Read and record the voltage across the zener diode and the current flowing through the zener diode

  E. Repeat steps C and D in one volt increments as specified in data table

  F. Return the power supply to zero volts, then reverse the connections of the zener diode

  (NOTE: The zener is now reverse biased.)

JOB SHEET #1

G. Set the power supply for 1 volt

H. Read and record the voltage across the zener diode and the current through the diode

I. Repeat step H while increasing the voltage in one volt steps to 15 Volts

J. Graph the forward and reverse characteristics (current versus voltage) for the zener diode from the values just measured

K. Check your calculations and your graph with your instructor

DATA:

FORWARD BIAS	
VOLTAGE (VOLTS)	CURRENT (MA)
0.1	
0.2	
0.3	
0.4	
0.5	
0.8	
1.0	
2.0	
4.0	
6.0	
8.0	
10.0	
12.0	
14.0	
15.0	

REVERSE BIAS	
VOLTAGE (VOLTS)	CURRENT (MA)
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	
15	

SPECIAL SEMICONDUCTOR DIODES
UNIT IV

JOB SHEET #2--CONSTRUCT AND TEST A ZENER DIODE VOLTAGE REGULATOR

I. Tools and equipment

A. Power supply (0-15V)

B. 2-DC voltmeters

C. 1-DC milliameter

D. 1-1K ohm resistor, 1/2 watt

E. 1-10K ohm resistor, 1/2 watt

F. 1-1N4739 zener diode or equivalent

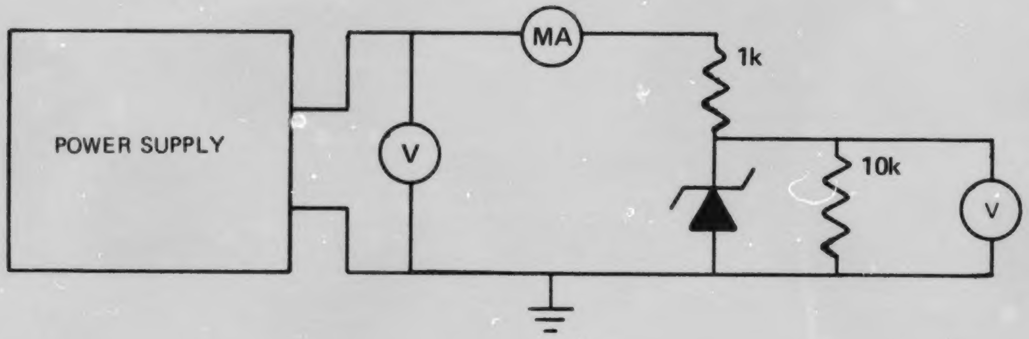
G. Graph paper

II. Procedure

A. Connect the circuit shown below

B. Adjust the power supply from zero to 15 volts in steps of 1 volt

C. For each value of power supply voltage read and record the voltage across the 10K ohm load resistor and circuit current



D. Graph power supply voltage versus load voltage for each data point

E. Check your calculations and your graph with your instructor

SPECIAL SEMICONDUCTOR DIODES
UNIT IV

NAME ______________________________

TEST

1. Match the terms on the right with their correct definitions.

______a. A silicon diode that is designed to operate at a specific reverse-breakdown voltage

______b. A diode that has a negative resistance characteristic and can be used as amplifiers, an oscillator, and an extremely fast switching device

______c. A diode which serves as a voltage-sensitive capacitor

______d. A diode specially doped to emit light when forward biased

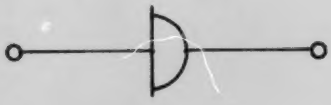
______e. A diode made from photo-sensitive material; the device's resistance decreases with increased light

______f. A special diode which uses a metal-to-semiconductor junction and is used for high-frequency rectification

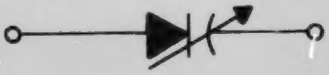
1. Tunnel diode
2. Varactor diode
3. Zener diode
4. Photo diode
5. Light-emitting diode
6. Hot-carrier diode

2. Select the schematic symbol for a zener diode from the symbols given below by circling the letter next to it.

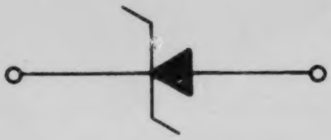
a.



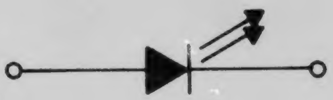
b.



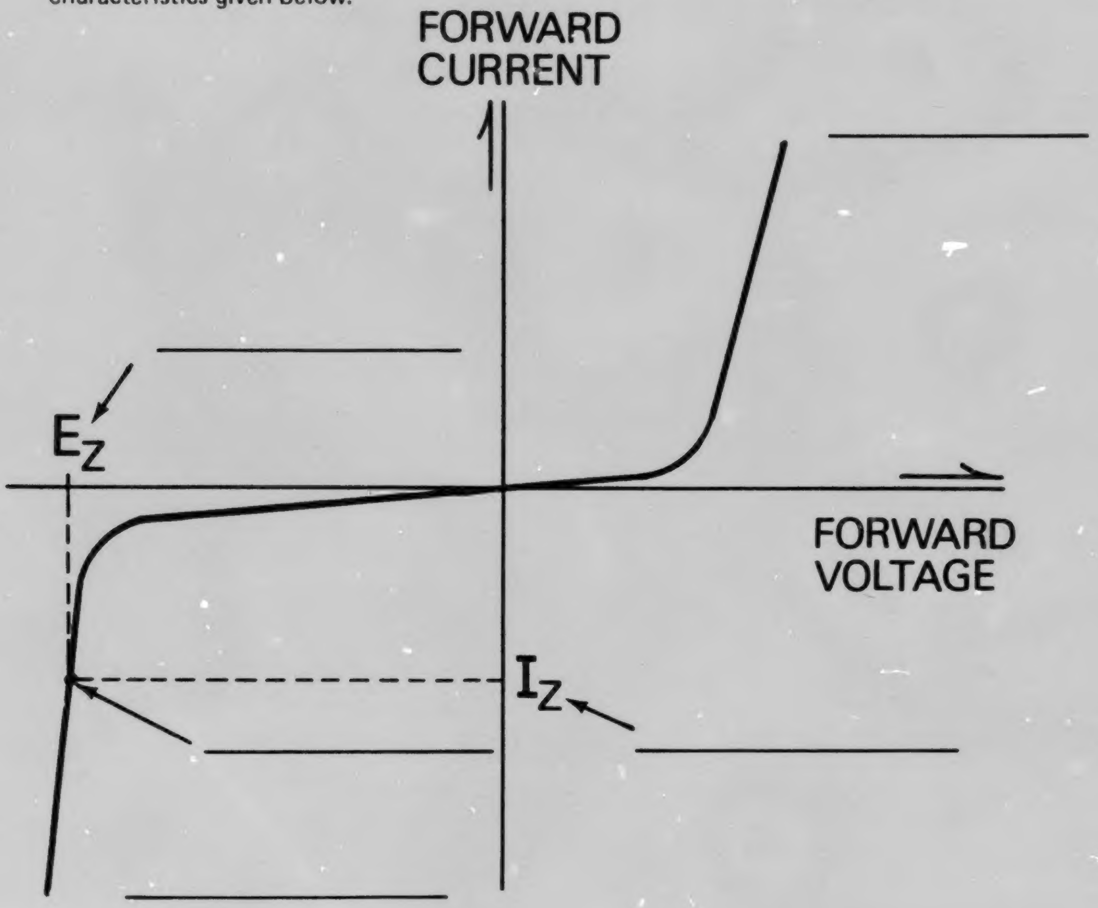
c.



d.



3. Identify the operating point, the zener voltage, the forward-bias region, the zener current, and the reverse-bias region of a zener diode from the zener volt/ampere characteristics given below.



4. List the alternate names for zener diodes.

a. ____________________________

b. ____________________________

5. Select the zener diode applications by placing an "X" in the appropriate blanks.

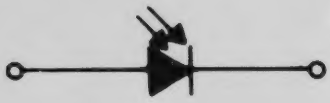
_____a. Voltage regulator

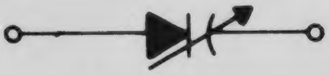
_____b. Amplifier

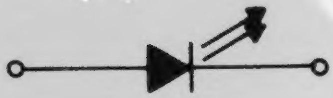
_____c. Reference element

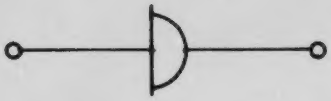
_____d. Switch

6. Select the schematic symbol for a tunnel diode from the symbols given below by circling the letter next to it.

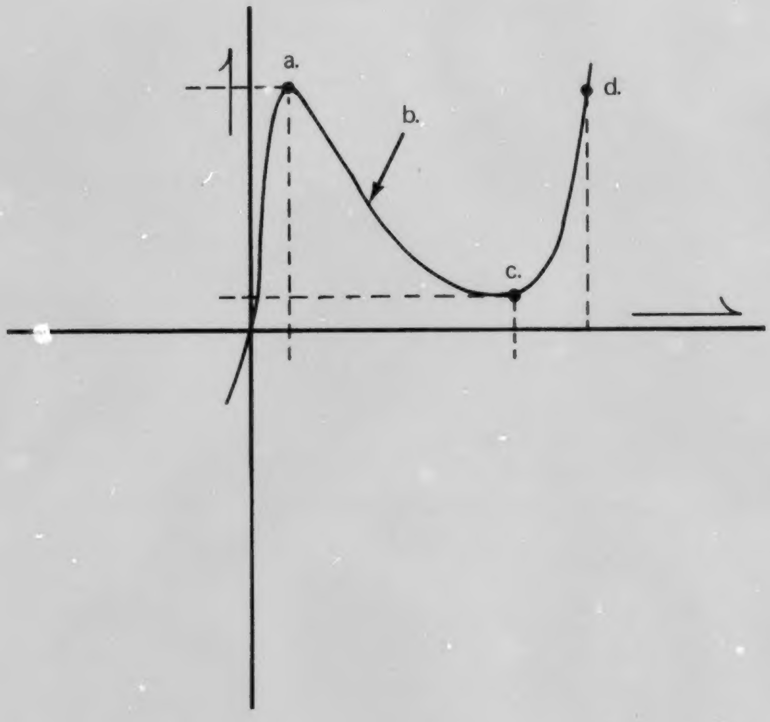
a.


b.


c.


d.


7. Identify the negative resistance region, peak point, valley point, and the forward point for a tunnel diode from the volt/ampere characteristics given below.



a. ______________________ c. ______________________

b. ______________________ d. ______________________

8. Select applications of tunnel diodes by placing an "X" in the appropriate blanks.

______a. Logic level indicators

______b. Amplifiers

______c. Oscillators

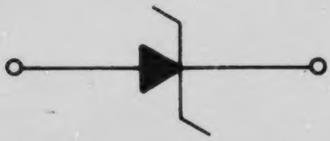
______d. Voltage regulators

______e. Switches

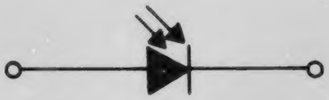
______f. Multivibrators

9. Select the schematic symbol for a varactor diode from the symbols given below by circling the letter next to it.

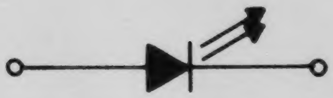
a.



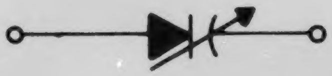
b.



c.



d.



10. Complete statements concerning bias voltage and barrier capacitance in varactor diodes by underlining the correct words in the sentences below.

a. The (larger) (smaller) the reverse bias, the (smaller) (larger) the barrier capacitance

b. The (larger) (smaller) the forward bias, the (larger) (smaller) the barrier capacitance

11. List alternate names for varactor diodes.

a. ____________________________________

b. ____________________________________

12. Select applications of varactor diodes by placing an "X" in the appropriate blanks.

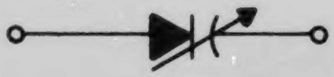
______a. Switches

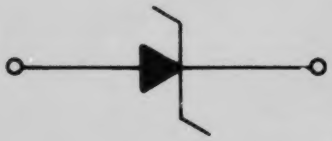
______b. Voltage regulators

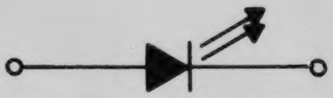
______c. Automatic frequency controls

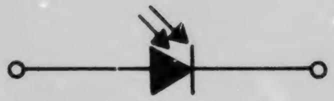
______d. Variable RC and LC filters

13. Select the schematic symbol for a light-emitting diode from the symbols given below by circling the letter next to it.

a.


b.


c.


d.


14. Complete statements concerning instantaneous-forward current versus light output in light-emitting diodes by underlining the correct words in the sentences below.

a. Light output (increases) (decreases) with forward current

b. There is no light output when LED is (forward) (reverse) biased

15. Select applications of light-emitting diodes by placing an "X" in the appropriate blanks.

______a. Electroluminescent displays

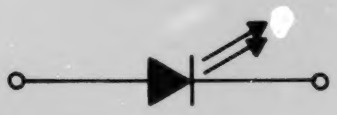
______b. Multivibrators

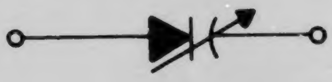
______c. Logic-level indicators

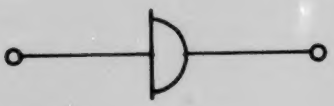
______d. Oscillators

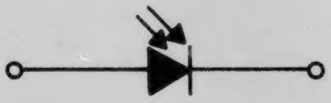
______e. Voltage regulators

16. Select the schematic symbol for a photo diode from the symbols given below by circling the letter next to it.

a.


b.


c.


d.


17. Complete statements concerning light-input intensity versus current-in photo diodes by underlining the correct words in the sentences below.

    a. An increase in input-light intensity (increases) (decreases) diode current

    b. For a given light-input intensity the diode current is (approximately) (exactly) constant for increased reverse-bias voltage

18. List three photo diode applications.

    a. ____________________________________

    b. ____________________________________

    c. ____________________________________

19. Demonstrate the ability to:

    a. Construct a volt/ampere characteristic curve for a zener diode.

    b. Construct and test a zener diode voltage regulator.

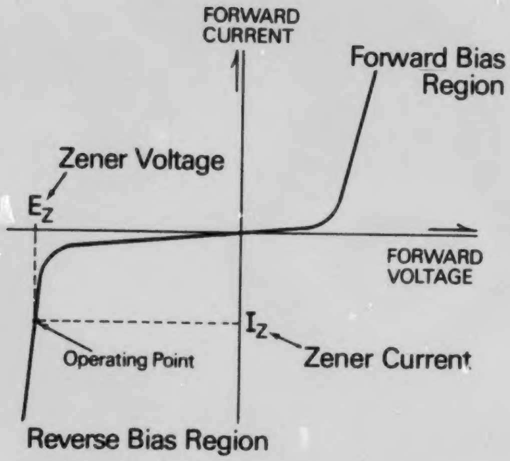
    (NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

SPECIAL SEMICONDUCTOR DIODES
UNIT IV

ANSWERS TO TEST

1. a. 3
   b. 1
   c. 2
   d. 5
   e. 4
   f. 6

2. c

3. 
FORWARD CURRENT
Forward Bias Region
Zener Voltage
E_Z
FORWARD VOLTAGE
I_Z
Operating Point
Zener Current
Reverse Bias Region

4. a. Reference diode
   b. Breakdown diode

5. a, c

6. d

7. a. Peak point
   b. Negative resistance region
   c. Valley point
   d. Forward point

8. b, c, e, f

9. d

10. a. The larger the reverse bias, the smaller the barrier capacitance
    b. The larger the forward bias, the larger the barrier capacitance

11. a. Varicaps
    b. Voltacaps

12. c, d

13. c

14. a. Light output increases with forward current
    b. There is no light output when LED is reverse biased

15. a, c

16. d

17. a. An increase in input-light intensity increases diode current
    b. For a given light-input intensity the diode current is approximately constant for increased reverse-bias voltage

18. a. Light-detection systems
    b. High speed card and tape readers
    c. Production line counting of objects which interrupt a light beam

19. Performance skills evaluated to the satisfaction of the instructor

BIPOLAR-JUNCTION TRANSISTORS
UNIT V

UNIT OBJECTIVE

After completion of this unit, the student should be able to identify the standard symbols and correct biasing arrangements for NPN and PNP transistors and draw and label the current flow in NPN and PNP transistor circuits. The student should also be able to test transistors. This knowledge will be evidenced by correctly performing the procedures outlined on the assignment and job sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to bipolar-junction transistors with their correct definitions.
2. Match transistor terms with their standard abbreviations.
3. Identify the basic elements in PNP and NPN transistor block diagrams and schematics.
4. Select the major uses of transistors.
5. State the base to emitter forward voltage drop for germanium and silicon transistors.
6. Identify the correct biasing arrangements for PNP and NPN transistors.
7. Draw the electron flow in NPN and PNP transistor circuits.
8. Distinguish between the typical types of transistors.
9. Label a transistor circuit.
10. Demonstrate the ability to test transistors.

BIPOLAR JUNCTION TRANSISTORS
UNIT V

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information, assignment, and job sheets.

III. Make transparencies.

IV. Discuss unit and specific objectives.

V. Discuss information and assignment sheets.

VI. Demonstrate and discuss the procedures outlined in the job sheet.

VII. Show various types of transistors.

VIII. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

  A. Objective sheet

  B. Information sheet

  C. Transparency masters

    1. TM 1--Transistor Block Diagrams and Schematic Symbols
    2. TM 2--Correctly Biased Transistors
    3. TM 3--Electron Flow in NPN and PNP Transistor Circuits
    4. TM 4--Typical Transistor Types

  D. Assignment sheet #1--Label a Transistor Circuit

  E. Answers to assignment sheet

  F. Job Sheet #1--Test Transistors

  G. Test

  H. Answers to test

II. References:

A. Grob, Bernard. *Basic Electronics*. 4th Ed., New York: McGraw-Hill Book Co., 1977.

B. Marcus, Abraham and Samuel C. Gendler. *Basic Electronics*. Englewood Cliffs, NJ: Prentice-Hall, Inc., 1971.

C. *Basic Electricity/Electronics*. Vol. 5, "Motors & Generators--How They Work." Indianapolis, IN: Howard W. Sams & Co., Inc.

D. *Fundamentals of Electricity*. Fort Sill, OK: Communication/Electronics Department, U.S. Army Field Artillery School.

BIPOLAR JUNCTION TRANSISTORS
UNIT V

INFORMATION SHEET

I. Terms and definitions

A. Bipolar junction transistor (BJT)--A three-terminal semiconductor current-controlled device that is normally used as a control switch or as a signal or power amplifier

B. Emitter--The section that supplies majority carriers

C. Collector--The section that collects majority carriers

D. Base--The secton used to control the flow of majority carriers (current) from emitter to collector

E. PNP transistor--One of the two major categories of bipolar transistors consisting of P-type material for the emitter, N-type material for the base, and P-type material for the collector

F. NPN transistor--One of the two major categories of bipolar transistors consisting of N-type material for the emitter, P-type material for the base, and N-type material for the collector

G. Bias--The voltages required to make the semiconductor devices (such as diodes and transistors) operate correctly

H. Bipolar--Two types of carriers, holes, and electrons flowing in transistors

(NOTE: The emitter-base junction must be forward biased while the base-collector junction must be reverse biased.)

II. Transistor terms and standard abbreviations

A. Transistor-base lead--B

B. Transistor-emitter lead--E

C. Transistor-collector lead--C

D. Base current--I_B

E. Emitter current--I_E

F. Collector current--I_C

INFORMATION SHEET

III. Basic elements in transistor block diagrams and schematics (Transparency 1)

  A. PNP transistors

    1. Block diagram

      a. Emitter

      b. Base

      c. Collector

    2. Schematic

      a. Emitter

      b. Base

      c. Collector

      (NOTE: The emitter arrow is pointing toward the N-type material and toward the base.)

  B. NPN transistors

    1. Block diagram

      a. Emitter

      b. Base

      c. Collector

    2. Schematic

      a. Emitter

      b. Base

      c. Collector

      (NOTE: The emitter arrow is pointing toward the N-type material and away from the base, which is P-type material.)

IV. Major uses of transistors

  A. Amplification

  B. Switching

INFORMATION SHEET

V. Forward voltage drop for transistors

   A. Germanium (Ge)--0.2 to 0.3 volts

   B. Silicon (Si)--0.6 to 0.7 volts

VI. Biasing arrangements for PNP and NPN transistors (Transparency 2)

   A. Emitter--Base has forward bias

   B. Base--Collector has reverse bias

   (NOTE: The difference in the PNP and NPN biasing arrangements is that polarity is reversed.)

VII. Electron flow in NPN and PNP transistor circuits (Transparency 3)

   A. PNP--Electrons flow from emitter to collector through external circuit

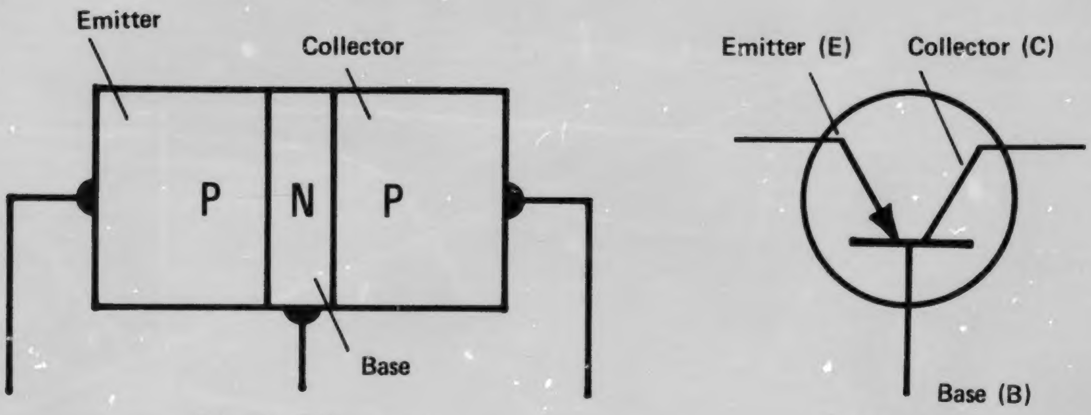
   B. NPN--Electrons flow from collector to emitter through external circuit

VIII. Typical transistor types (Transparency 4)

   A. Small signal--Relatively small and handles small currents

   B. Power--Relatively large and handles large currents

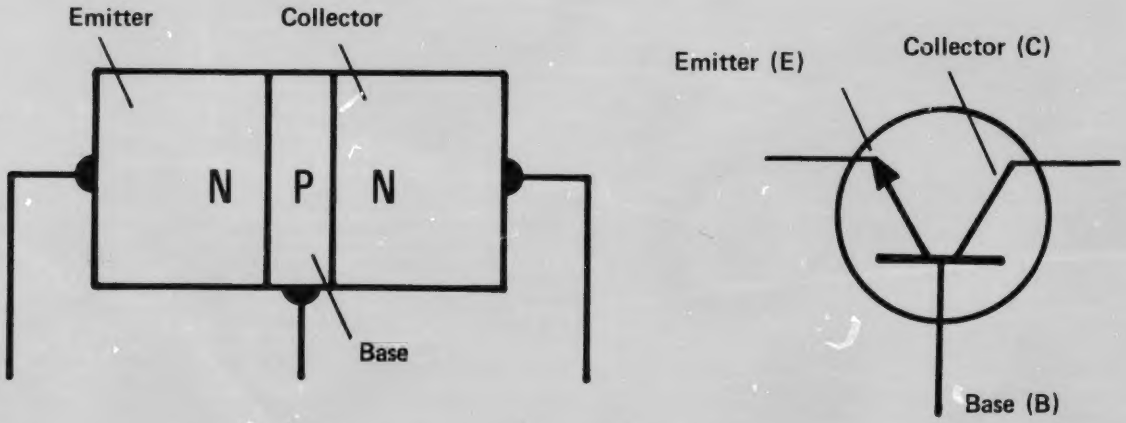
Transistor Block Diagrams and Schematics


Emitter
Collector
P
N
P
Base
Emitter (E)
Collector (C)
Base (B)

Block Diagram

Schematic

PNP Transistor


Emitter
Collector
N
P
N
Base
Emitter (E)
Collector (C)
Base (B)

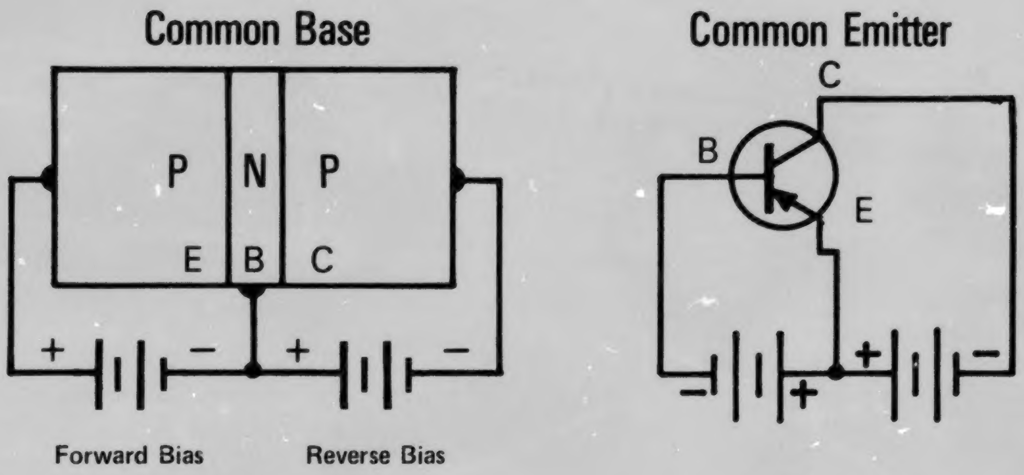
Block Diagram

Schematic

NPN Transistor

(NOTE: In both PNP and NPN transistors, the arrow on the emitter lead points toward the N-type material.)

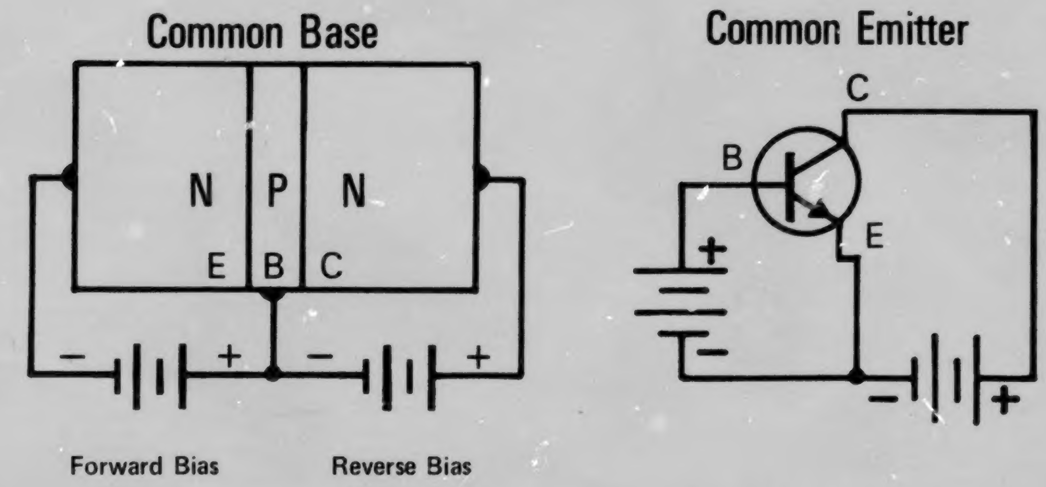
Correctly Biased Transistors


Common Base
Common Emitter
P
N
P
E
B
C
+
−
+
−
Forward Bias
Reverse Bias
C
B
E
−
+
+
−

Block

Schematic

PNP Transistor Bias

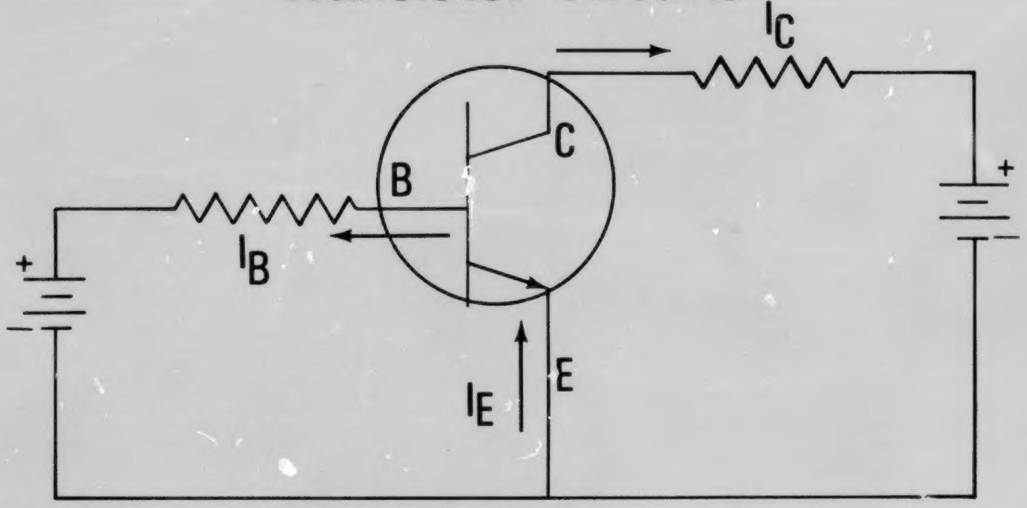

Common Base
Common Emitter
N
P
N
E
B
C
−
+
−
+
Forward Bias
Reverse Bias
C
B
E
+
−
−
+

Block

Schematic

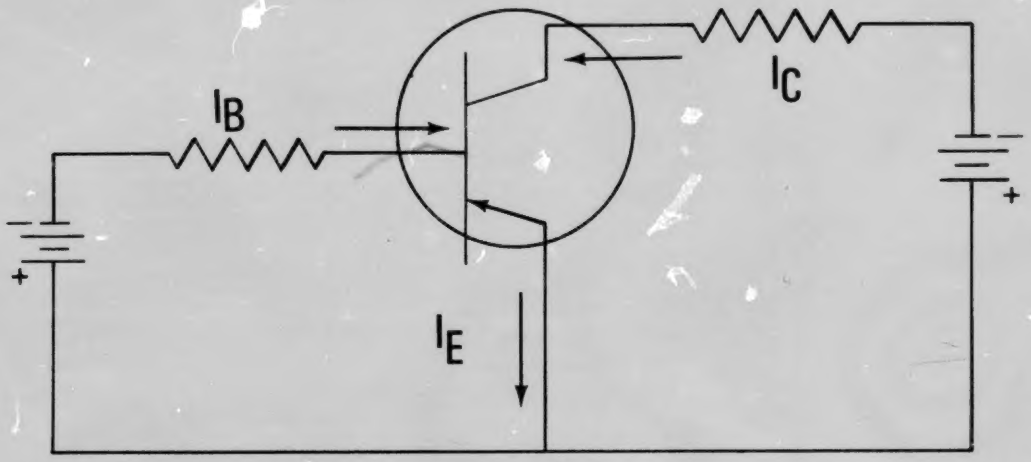
NPN Transistor Bias

Electron Flow in NPN and PNP Transistor Circuits



$I_E = I_B + I_C$

NPN Circuit

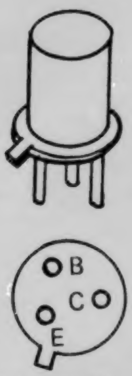


$I_E = I_B + I_C$

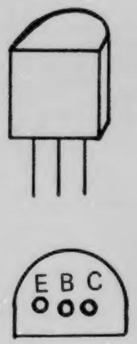
PNP Circuit

Typical Transistor Types

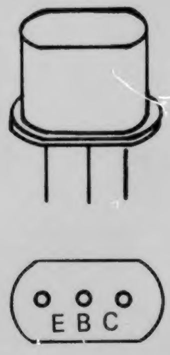
Small Signal Transistors



(Bottom View)

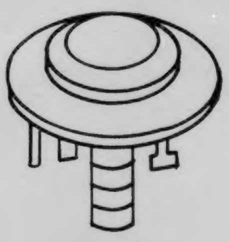


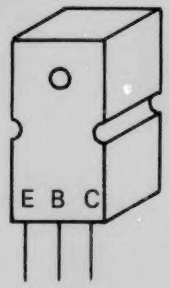
(Bottom View)

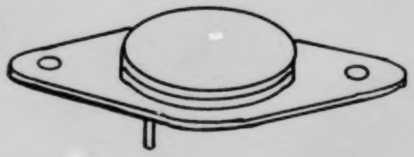


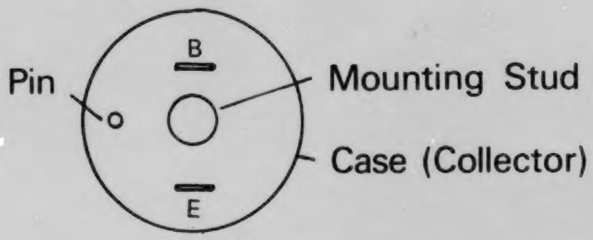
(Bottom View)

Power Transistors

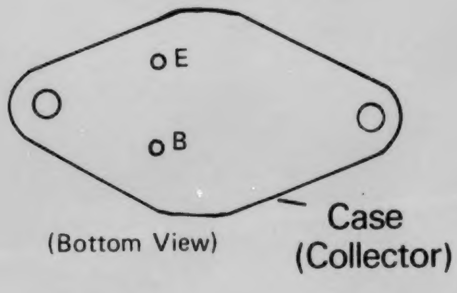







B
Pin
Mounting Stud
Case (Collector)
E

(Bottom View)


E
B
Case (Collector)

(Bottom View)

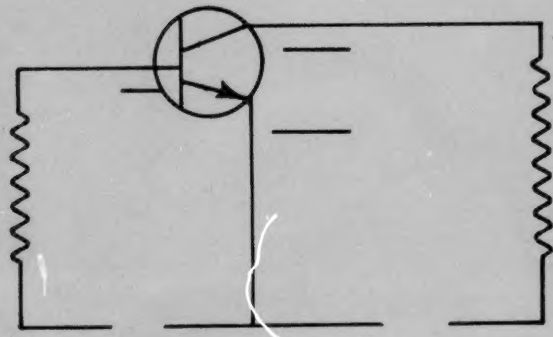
(NOTE: There may be other base diagrams)

TRANSISTORS
UNIT V

ASSIGNMENT SHEET #1--LABEL A TRANSISTOR CIRCUIT

Directions: On the transistor circuit below, label or draw the following:

- a. Category of transistor
  - 1. NPN
  - 2. PNP
- b. Leads
  - 1. Emitter
  - 2. Base
  - 3. Collector
- c. Draw in the correct battery-bias supplies
- d. Electron circuit flow
  - 1. I_E
  - 2. I_B
  - 3. I_C

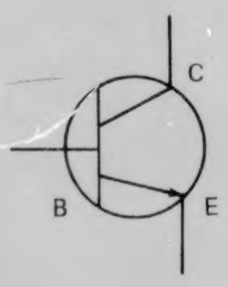


TRANSISTORS
UNIT V

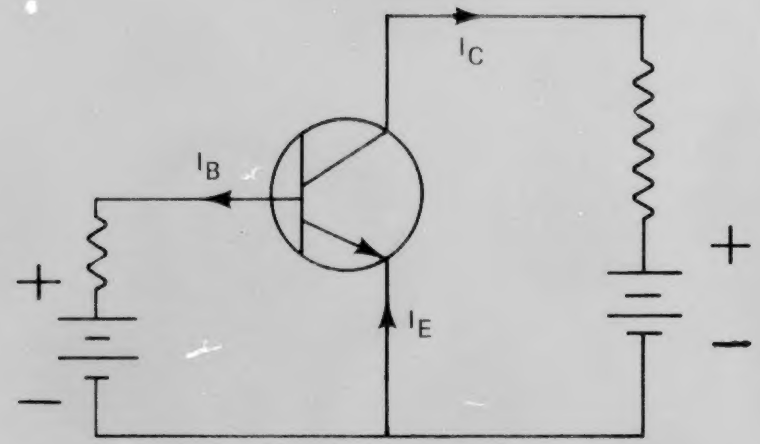
ANSWERS TO ASSIGNMENT SHEET #1

a. NPN

b.



c.



TRANSISTORS
UNIT V

JOB SHEET #1--TEST TRANSISTORS

I. Tools and equipment

A. Assortment of transistors (both signal and power types)

B. Ohmmeter

C. Transistor tester (if available)

II. Procedure

A. Carefully examine the assortment of transistors and note the differences in size, shape, and lead arrangements

B. Choose two signal transistors and one power transistor

C. Determine which ohmmeter lead is positive and which is negative

(NOTE: Either get this from the manufacturer's instruction book or by measuring the voltage with a voltmeter.)

D. Identify the emitter, base, and collector leads

E. Place the ohmmeter on R x 100 range

(NOTE: This is necessary because there may be too much voltage if the ohmmeter is placed in a high range.)

F. Determine the forward-biased emitter base junction

1. Place the positive ohmmeter lead on the emitter lead and the negative ohmmeter lead on the base lead
2. Note the resistance reading
3. Place the negative ohmmeter lead on the emitter and the positive ohmmeter lead on the base
4. Note the resistance reading
5. Compare the two resistance readings
6. Repeat steps 1 through 5 for the collector-base junction
7. From above reading, determine whether the transistor is good or bad
8. If the transistor tested was good, state whether it is PNP or NPN
9. If the transistor tested was bad, state where it was open or shorted

JOB SHEET #1

G. If your lab has a transistor tester, following the instructions given in operations manual, check the transistor

H. Check your findings with your instructor

DATA CHART

EMITTER-BASE JUNCTION

R_{EB} ____________

R_{BE} ____________

COLLECTOR-BASE JUNCTION

R_{CB} ____________

R_{BC} ____________

TYPE OF TRANSISTOR ________________

BIPOLAR JUNCTION TRANSISTORS
UNIT V

NAME______________________________

TEST

1. Match the terms on the right with their correct definitions.

______a. The section that collects majority carriers

______b. The voltages required to make the semiconductor devices operate correctly

______c. The section used to control the flow of majority carriers from emitter to collector

______d. The section that supplies majority carriers

______e. One of the two major categories of bipolar transistors consisting of P-type material for the emitter, N-type material for the base, and P-type material for the collector

______f. A three-terminal semiconductor current-controlled device that is normally used as a control switch or as a signal or power amplifier

______g. One of the two major categories of bipolar transistors consisting of N-type material for the emitter, P-type material for the base, and N-type material for the collector

______h. Two types of carriers, holes, and electrons flowing in transistors

1. Bipolar junction transistor
2. Emitter
3. Collector
4. Base
5. NPN transistor
6. PNP transistor
7. Bias
8. Bipolar

2. Match transistor terms with their standard abbreviations.

______a. I_B

______b. C

______c. E

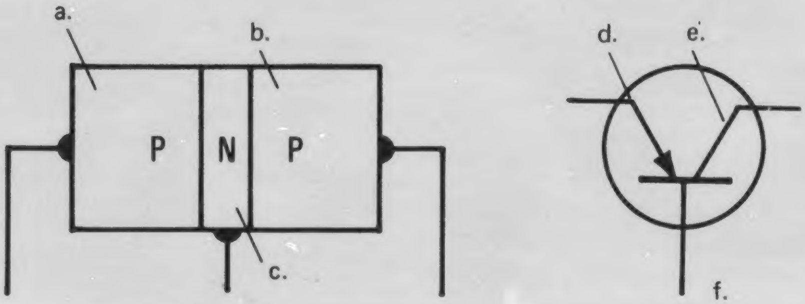
______d. I_E

______e. B

______f. I_C

1. Transistor-base lead
2. Transistor-emitter lead
3. Transistor-collector lead
4. Base current
5. Emitter current
6. Collector current

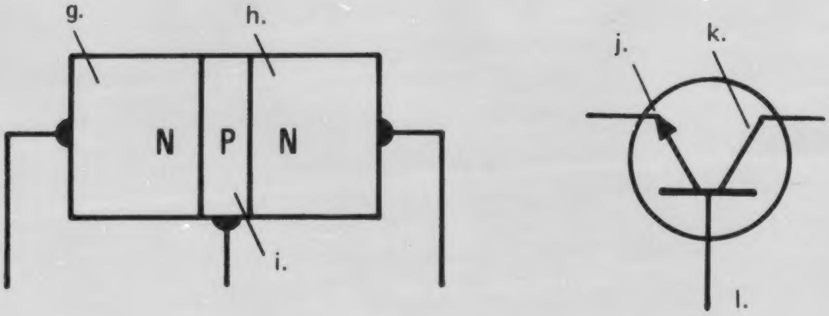
3. Identify the basic elements in PNP and NPN transistor block diagrams and schematics.



Block Diagram

Schematic

PNP Transistor



Schematic

NPN Transistor

a. ____________________

b. ____________________

c. ____________________

d. ____________________

e. ____________________

f. ____________________

g. ____________________

h. ____________________

i. ____________________

j. ____________________

k. ____________________

l. ____________________

4. Select the major uses of transistors by placing an "X" in the appropriate blank.

_____a. Amplification

_____b. Oscillation

_____c. Switching

_____d. Transforming

_____e. Energy storage

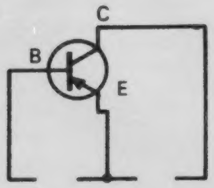
5. State the base to emitter forward voltage drop for germanium and silicon transistors.

a. Germanium _____ to _____ volts

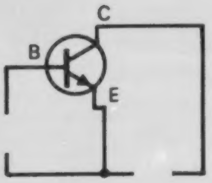
b. Silicon _____ to _____ volts

6. Identify the correct biasing arrangements for PNP and NPN transistors by drawing the battery connections in the circuit schematics below.

a. PNP

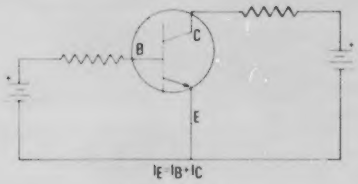


b. NPN



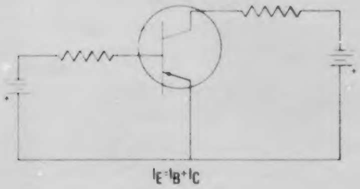
7. Draw the correct election flow in NPN and PNP transistor circuits.

a.



NPN Circuit

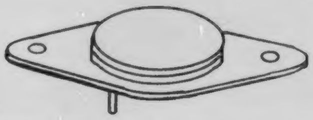
b.



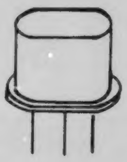
PNP Circuit

8. Distinguish between small signal and power transistors by placing an "X" next to the signal transistors.

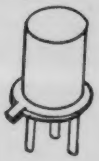
______a.



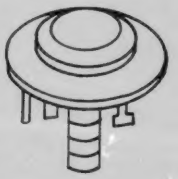
______b.



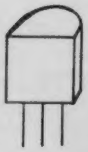
______c.



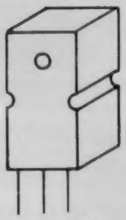
______d.



______e.



______f.



9. Label a transistor circuit.
10. Demonstrate the ability to test transistors.

(NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

BIPOLAR JUNCTION TRANSISTORS
UNIT V

ANSWERS TO TEST

1. a. 3 e. 6
   b. 7 f. 1
   c. 4 g. 5
   d. 2 h. 8

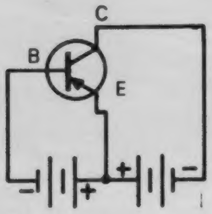
2. a. 4
   b. 3
   c. 2
   d. 5
   e. 1
   f. 6

3. a. Emitter e. Collector (C) i. Base
   b. Collector f. Base (B) j. Emitter (E)
   c. Base g. Emitter k. Collector (C)
   d. Emitter (E) h. Collector l. Base (B)

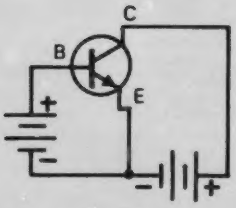
4. a, c

5. a. 0.2 to 0.3 volts
   b. 0.6 to 0.7 volts

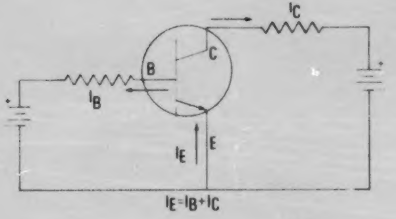
6. a. PNP



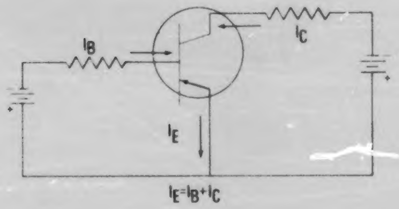
   b. NPN



7. a. PNP


I_C
C
B
I_B
I_E
E
$I_E=I_B+I_C$

b. NPN


I_B
I_C
I_E
$I_E=I_B+I_C$

8. b, c, e

9. Evaluated to the satisfaction of the instructor

BIPOLAR-JUNCTION TRANSISTOR CIRCUITS
UNIT VI

UNIT OBJECTIVES

After completion of this unit, the student should be able to identify transistor circuits, state the relative values of current voltage and power gain in decibels, and list the most common applications for basic transistor circuit types. The student should also be able to construct and test each of the basic transistor circuit types and demonstrate the ability to plot the output characteristic curves for a common-emitter transistor circuit. This knowledge will be evidenced by correctly completing the procedures outlined in the assignment and job sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to bipolar-junction transistor circuits with their correct definitions.
2. Identify the basic types of transistor circuits.
3. Match transistor circuits with terms or values associated with circuit current gain.
4. Complete a table showing the gain characteristics of basic transistor types.
5. State which types of transistor circuits give signal voltage phase reversal.
6. Match transistor circuits with their common applications.
7. Complete a table showing the relative magnitudes of the input and output impedances for basic transistor circuits.
8. Compute voltage, current, and power stage gain in decibels.
9. Demonstrate the ability to:
    a. Construct and test a common-emitter circuit.
    b. Construct and test a common-base circuit.
    c. Construct and test a common-collector circuit.
    d. Plot a transistor output characteristic curve.

BIPOLAR-JUNCTION TRANSISTOR CIRCUITS
UNIT VI

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information, assignment, and job sheets.

III. Make transparencies.

IV. Discuss unit and specific objectives.

V. Discuss information and assignment sheets.

VI. Demonstrate and discuss the procedures outlined in the job sheets.

VII. Show various types of transistors.

VIII. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

- A. Objective sheet
- B. Information sheet
- C. Transparency masters
  - 1. TM 1--Circuit Schematic Diagrams
  - 2. TM 2--Gain Characteristics of Basic Transistor Types
  - 3. TM 3--Impedance Characteristics
- D. Assignment Sheet #1--Compute Voltage, Current, and Power Stage Gain in Decibels
- E. Answers to assignment sheet
- F. Job sheets
  - 1. Job Sheet #1--Construct and Test a Common-Emitter Circuit
  - 2. Job Sheet #2--Construct and Test a Common-Base Circuit

3. Job Sheet #3--Construct and Test a Common-Collector Circuit

4. Job Sheet #4--Plot a Transistor Output Characteristic Curve

II. Reference--Grob, Bernard. *Basic Electronics.* New York: McGraw-Hill Book Co., 1977.

BIPOLAR-JUNCTION TRANSISTOR CIRCUITS
UNIT VI

INFORMATION SHEET

I. Terms and definitions

   A. Gain--Ratio of the output quantity to input quantity, often abbreviated as "A"

   B. Voltage gain (A_v)--Output voltage divided by input voltage

   C. Current gain (A_i)--Output current divided by input current

   D. Power gain (A_p)--Output power divided by input power

   E. Input impedance--The impedance of a circuit as viewed from its input terminals

   F. Output impedance--The impedance of a circuit as viewed from the output terminals

   G. db (decibel)--A ratio of an output level to an input level

II. Basic types of transistor circuits (Transparency 1)

   A. Common emitter

   B. Common base

   C. Common collector

   (NOTE: For PNP transistor, reverse-bias polarity of battery terminals.)

III. Transistor circuit current gain (Ai)

   A. Common emitter

      1. h_{fe}

      2. Beta or β

      3. Much greater than 1; typical current gain value = 50

   B. Common base

      1. h_{fb}

      2. Alpha or α

      3. Current gain less than 1; typically 0.95 to 0.99

INFORMATION SHEET

C. Common collector
  1. Current gain is greater than 1
  2. Called emitter follower

IV. Gain characteristcs of the basic transistor types (Transparency 2)

A. Common emitter
  1. $A_v =$ high (300)
  2. $A_i = h_{fe} = \beta =$ high (50)
  3. $A_p =$ very high (15,000)

B. Common base
  1. $A_v =$ high (500)
  2. $A_i = h_{fb} = \beta =$ low (0.97)
  3. $A_p =$ medium (485)

C. Common collector
  1. Av = low (less than 1)
  2. Ai = high (50)
  3. Ap = low (48)

V. Signal voltage phase reversal

A. CE - yes

B. CB - no

C. CC - no

VI. Transistor circuits and their common applications

A. CE - Small signal amplification

B. CB - High frequency power amplification (current regulation)

C. CC - Voltage follower (impedance matching)

INFORMATION SHEET

VII. Impedance Characteristics (Transparency 3)

A. CE

1. Input impedance - Medium (1,000 ohms)
2. Output impedance - Medium (50,000 ohms)

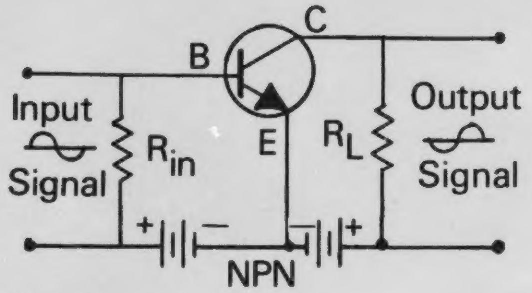
B. CB

1. Input impedance - Low (60 ohms)
2. Output impedance - High (1 Meg ohm)

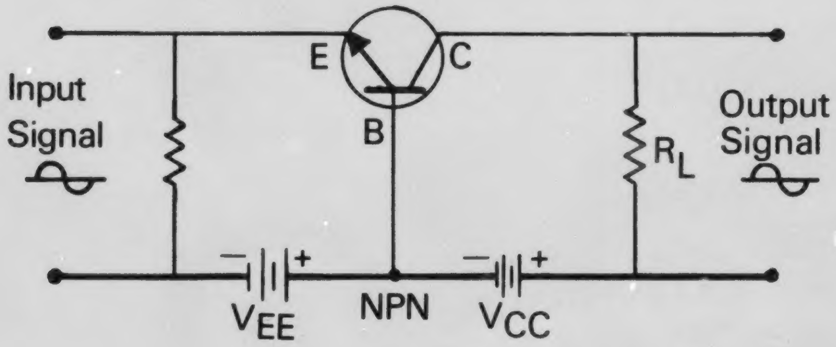
C. CC

1. Input impedance - High (400,000 ohms)
2. Output impedance - Low (100 ohms)

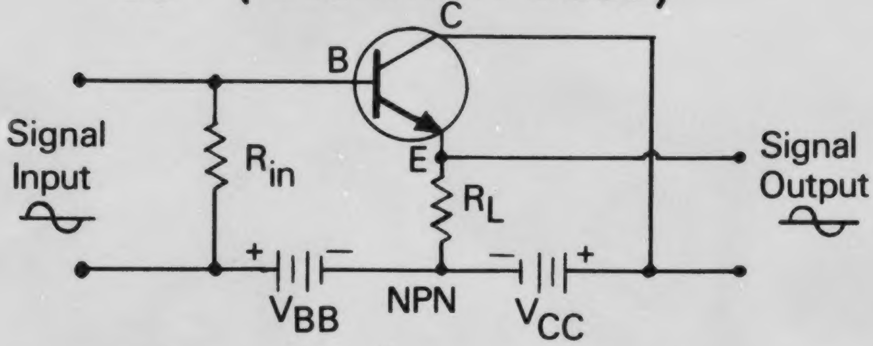
Circuit Schematic Diagrams


C
B
Input
Signal
R_{in}
E
R_L
Output
Signal
+
−
−
+
NPN

CE (Common Emitter)


E
C
Input
Signal
B
R_L
Output
Signal
−
+
−
+
V_{EE}
NPN
V_{CC}

CB (Common Base)


C
B
Signal
Input
R_{in}
E
R_L
Signal
Output
+
−
−
+
V_{BB}
NPN
V_{CC}

CC (Common Collector)

For PNP Transistors Reverse The Polarity of Battery Terminals

Gain Characteristics of Basic Transistor Types

Characteristics	Common Emitter	Common Base	Common Collector
Voltage Gain $A_V = \frac{V\,Out}{V\,In}$	High (300)	High (500)	Low Less Than One
Current Gain $A_i = \frac{I\,Out}{I\,In}$	High (50)	Less Than One (0.97)	High (50)
Power Gain $A_p = \frac{P\,Out}{P\,In}$	Very High (15,000)	Medium (400)	Low (30)

Impedance Characteristics

Characteristics	Common Emitter	Common Base	Common Collector
Input Impedance	Medium (1,000)	Low (60)	High (400,000)
Output Impedance	Medium (50,000)	High (1 M)	Low (100)

BIPOLAR-JUNCTION TRANSISTOR CIRCUITS
UNIT VI

ASSIGNMENT SHEET #1--COMPUTE VOLTAGE, CURRENT, AND POWER STAGE GAIN IN DECIBELS

Directions: Using the formulas given below, convert the gain values to their equivalent db value.

I. Formulas

A. Voltage gain--20 log Av = gain in db

B. Current gain--20 log Ai = gain in db

C. Power gain--10 log Ap = gain in db

Example: If voltage gain is 100, then the gain in db would be 20 times the log of 100 which is equal to 20 x 2 or a db gain of 40

II. Problems

A. Voltage gain

1. $A_v = 100$ db gain = ____________

2. $A_v = 75$ db gain = ____________

B. Current gain

1. $A_i = 1$ db gain = ____________

2. $A_i = .96$ db gain = ____________

C. Power gain

1. $A_p = 25$ db gain = ____________

2. $A_p = 2$ db gain = ____________

BIPOLAR-JUNCTION TRANSISTOR CIRCUITS
UNIT VI

ANSWERS TO ASSIGNMENT SHEET #1

A. 1. 40 db

2. 37.5 db

B. 1. 0 db

2. -0.35 db

C. 1. 13.98 db

2. 3.01 db

BIPOLAR-JUNCTION TRANSISTOR CIRCUITS
UNIT VI

JOB SHEET #1--CONSTRUCT AND TEST A COMMON-EMITTER CIRCUIT

I. Tools and equipment

A. 1 NPN transistor (2N1304 transistor)

B. Microammeter and 2 milliameters (or 3 multimeters-zero to 50mA range)

C. VTVM

D. Oscilloscope

E. Audio signal generator

F. 1-1M resistor. 1-47K resistor, 1-1K resistor, 1-10K and 1-1K potentiometer (use 1/2 watt resistor)

(NOTE: Resistor values may vary for your particular transistor)

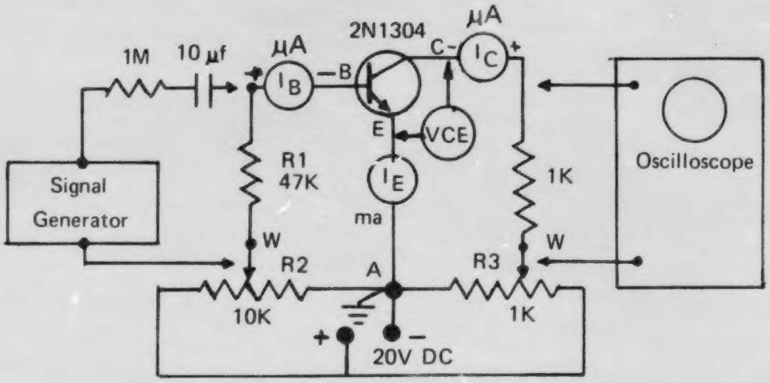
G. 1-10 μF capacitor

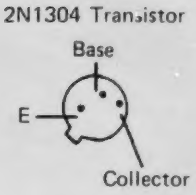
H. Power supply 0-20VDC

II. Procedure

A. Do not turn on power supply at this time

B. Connect the circuit as shown below


1M
10 µf
µA
I_B
B
2N1304
C
µA
I_C
+
E
VCE
R1
47K
I_E
ma
1K
Signal Generator
Oscilloscope
W
R2
A
R3
W
10K
1K
+
−
20V DC


2N1304 Transistor
Base
E
Collector

(NOTE: If you do not have a microammeter for I_B insert a 100 ohm resistor in series and use your VTVM to read the voltage drop. Then, compute the current from the VTVM reading and the value of the resistor.)

JOB SHEET #1

C. Have your instructor approve your circuit wiring

D. Set the potentiometers to zero ohms between points A and W

E. Set the power supply for 20V DC

F. Adjust the collector potentiometer R_3 until V_{ce} is 6.0 volts

G. Adjust the base resistor R_2 until the base current, I_B, is 20 microamperes

H. Recheck V_{ce} to see that it has remained at 6.0 volts

(NOTE: It may be necessary to readjust R_3 to maintain V_{ce} = 6 volts and $I_a = 20\ \mu A$.)

I. Read and record I_c when V_{ce} = 6.0 v and $I_B = 20\mu A$

J. Using your VTVM read and record the base-emitter DC voltage

K. Increase the base resistor, R_2, until I_B is 40 microamperes

L. Recheck V_{ce} = 6.0 volts, adjust R_3 as needed

M. Read and record I_c when V_{ce} = 6.0 v and $I_B = 40\ \mu A$

N. Connect the signal generator across the 47K input resistor, and set the output frequency to 1 KHz

O. Turn the signal generator on and adjust the input signal, e_{in}, across the input resistor R_1 to 10 mV rms value

P. Use the oscilloscope to view this waveshape and make a sketch of the waveshape showing frequency and amplitude

Q. Move the oscilloscope to observe the output voltage across the 1K ohm output resistor

R. Make a sketch of the output waveform, showing amplitude and frequency

S. Compute and record the output voltage, e_o, in rms

T. Compute the output current, i_{out}, by dividing the output voltage, e_o, by the load resistance, 1K

U. Measure the rms voltage across the 1 M ohm series resistor

V. Compute and record the input current i_{in}

W. Calculate the current gain by dividing i_{out} by i_{in}, and express your answer in db

X. Have your instructor check your calculations

JOB SHEET #1

Data Table

DC measurements

	I_E	I_B	I_C	V_{BE}
$V_{CE} = 6v$		20µA		
$V_{CE} =$		40µA		
$A_I =$				

AC measurements

	P-P	rms
V_{in}		
i_{in} calculated		
V_{out}		
i_{out}		
A dB= Cal.		
A_idB cal.		
A_pdB cal.		

BIPOLAR-JUNCTION TRANSISTOR CIRCUITS
UNIT VI

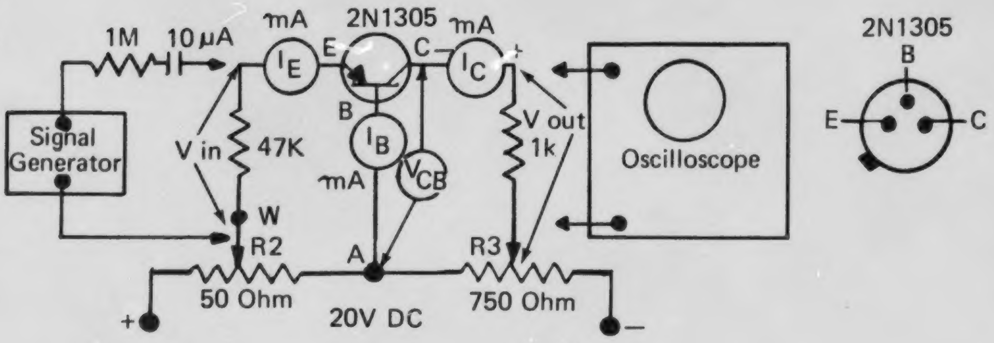
JOB SHEET #2--CONSTRUCT AND TEST A COMMON-BASE CIRCUIT

I. Tools and equipment

- A. 1-PNP transistor (2N1305 or equivalent)
- B. Variable power supply (0-20V DC)
- C. Oscilloscope
- D. Audio signal generator
- E. VTVM
- F. Microammeter (or multimeter)
- G. 2-milliammeters (or multimeter)
- H. Resistor 1-1K, 1-47K, 1-1M (use 1/2 watt resistor)
- I. One capacitor - 10µf
- J. Potentiometers - 50 ohm, 1W & 750 ohm, 1W

II. Procedure

- A. Do not turn on power supply at this time
- B. Connect the circuit as shown below


1M
10µA
mA
2N1305
mA
E
C
I_E
I_C
+
B
I_B
Signal Generator
V in
47K
mA
V_{CB}
V out
1k
Oscilloscope
W
R2
A
R3
+
50 Ohm
20V DC
750 Ohm
−
2N1305
B
E
C

JOB SHEET #2

C. Have your instructor check your circuit wiring

D. Adjust potentiometer R_2 until the resistance between point A and point W reads zero ohms

E. Turn on power supply and set for 20 volts

F. Adjust potentiometer R_3 until V_{CB} reads 5.8 Volts

G. Adjust potentiometer R_2 until the collector current reads 25 mA

H. Read and record I_C, I_B, and I_E

I. Adjust potentiometer R_2 to obtain a 20 microamp increase in I_B

J. Measure and record I_C, I_B, and I_E

K. Measure V_{EB} with the VTVM

L. State whether your transistor is germanium or silicon

M. Connect the signal generator across to 47K input resistor

N. Set the signal generator for 1 KHz

O. Adjust the signal generator until the voltage across the 47K input resistor reads 10mV rms

P. Using the oscilloscope, observe the waveshape of the voltage e_{in} across the 47K input resistor

Q. Sketch the waveshape of e_{in} showing frequency and amplitude

R. Measure the rms voltage across the 1M resistor and compute the rms input current, i_{in}

S. Using the oscilloscope, observe the waveshape of the voltage e_o across the 1K load resistor

T. Sketch the waveshape of e_o showing amplitude and frequency

U. Calculate the rms value of e_o

V. Calculate the rms value of the output current, i_o

W. Calculate the voltage gain of the circuit

X. Express the voltage gain of the circuit in db

Y. Have your instructor check your calculations

(NOTE: Remember to convert peak-to-peak voltage readings from scope to rms value)

JOB SHEET #2

Data Table

DC measurements

	VCE	I_C	I_B	I_E	$\frac{\Delta I_C}{\Delta I_B}$
Test 1 (step H)	25μA				
Test 2 (step J)					

AC measurements

	P-P	RMS
e_{in}		
V_{in}		
i_{in}		
$e_{o\,(Vix)}$		
i_O		
A_V		
A_VdB		

BIPOLAR-JUNCTION TRANSISTOR CIRCUITS
UNIT VI

JOB SHEET #3--CONSTRUCT AND TEST A COMMON-COLLECTOR CIRCUIT

I. Tools and equipment

A. Variable power supply (0-20V)

B. 1-PNP transistor (2N1305 or equivalent)

C. Oscilloscope

D. Signal generator

E. VTVM

F. 1 - 10μf capacitor

G. Resistors - 1 47K, 1-1K, 1-1M (use 1/2 watt resistor)

H. Microammeter (multimeter)

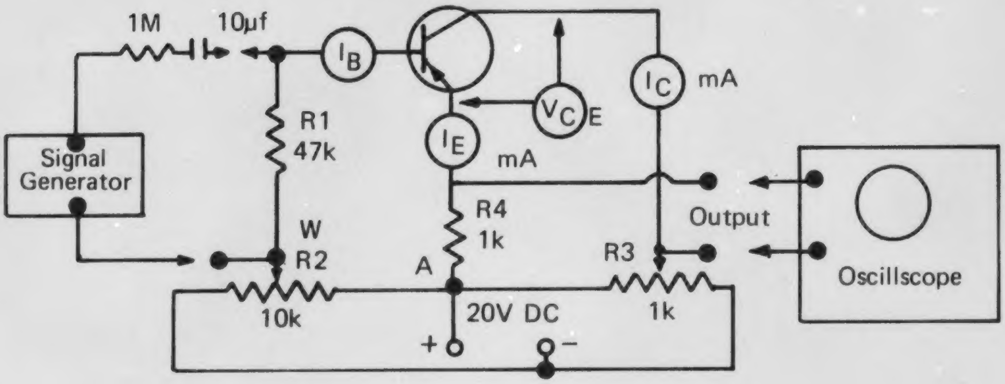
I. Two milliammeters (multimeters)

J. Potentiometers - 1-10K, 1-1K (use 1 watt potentiometer)

II. Procedure

A. Do not turn on power supply at this time

B. Connect recircuit as shown below


1M
10µf
IB
IC
mA
VCE
IE
mA
R1
47k
Signal Generator
W
R2
10k
A
R4
1k
R3
1k
Output
Oscillscope
20V DC
+
−

JOB SHEET #3

C. Have your instructor approve your circuit wiring

D. Set potentiometer R_2 to zero ohms between points A and W

E. Set the power supply to 20 volts

F. Adjust potentiometer R_2 until I_B reads 20 μA

G. Adjust potentiometer R_3 until V_{ce} as measured by the VTVM reads 6 volts

H. Measure and record I_E, I_B, and I_C

I. Adjust potentiometer R_2 until I_B reads 40 μA

J. Measure and record I_E, I_B, I_C

K. Measure V_{BE} with the VTVM and determine if the transistor is germanium or silicon

L. Connect the signal generator across the input resistor (47K)

M. Connect the VTVM across the 47K resistor and adjust the signal generator at 1KHz until the VTVM reads 10mV, rms

N. Read the rms voltage across the 1 meg ohm resistor

O. Calculate the input current

P. Sketch the waveshape of the input voltage showing both amplitude and frequency, as displayed on the oscilloscope

Q. Sketch the observed output waveshape across the 1K load resistor and calculate the rms output voltage

R. Calculate the rms value of the output current, i_o

S. Calculate the circuit's power gain and express the value in db

T. Have your instructor check your calculations

JOB SHEET #3

Data Table

DC measurements

V_{CE}	I_C	I_B	I_E	$\frac{\Delta I_C}{\Delta I_B}$
6.0V		20μA		
6.0V		40μA		

AC measurements

	P-P	RMS
I_{in}		
I_{out}		
V_{ik}		
I_{out}		
V_{1m}		
I_{in}		
A_i		
A_{idB}		

BIPOLAR-JUNCTION TRANSISTOR CIRCUITS
UNIT VI

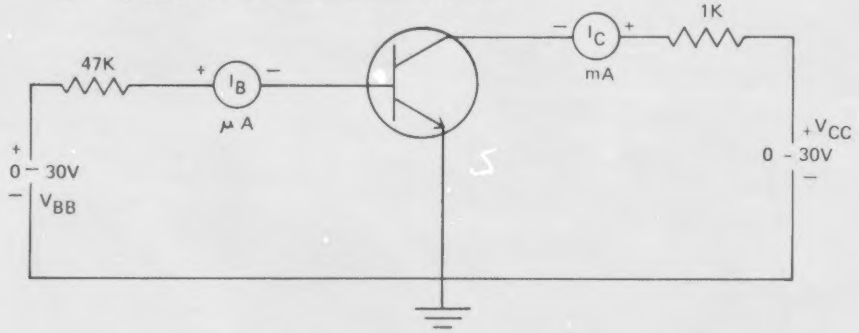
JOB SHEET #4--PLOT A TRANSISTOR OUTPUT CHARACTERISTIC CURVE

I. Tools and equipment

- A. 1-NPN transistor (2N1304 transistor)
- B. 1-microammeter and 2-milliameters (or three multimeters)
- C. VTVM
- D. 2-power supplies (0-20V DC)
- E. Graph paper

II. Procedure

- A. Do not turn on power supply at this time
- B. Connect the circuit as shown below



- C. Set the V_{BB} power supply until I_B reads 20 μA
- D. Record this value
- E. Adjust the V_{CC} power supply for voltages from 0 to 15 volts and record the value of I_C for each voltage reading

  (NOTE: It will be necessary to use small voltage clamps for V_{CC} between 0 and 5 volts. This will allow more measurements for I_C at the points where I_C rises rapidly.)
- F. Set V_{CC} back to 0 volts
- G. Readjust V_{BB} for I_B equal to 40 μA
- H. Record this value

JOB SHEET #4

I. Readjust V_{CC} from 0 to 15 volts, recording the value of I_C at each value of V_{CC}

J. Set V_{CC} equal to 0 volts

K. Readjust V_{BB} for I_B equal to 60 μA

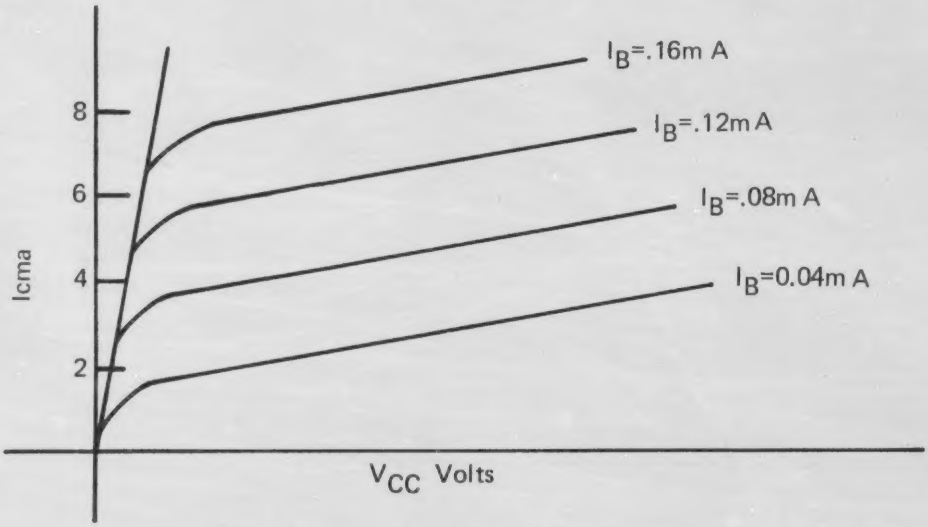
L. Record this value

M. Readjust V_{CC} from 0 to 15 volts, recording the values of I_C at each value of V_{CC}

N. Ask your instructor how many settings of I_B you should use

O. Plot a graph showing the relationship between I_B, I_C, and V_{CC}

(NOTE: The following is a sample of what your graph should look like.)



DATA TABLE

$I_B = 20\ \mu A$

V_{CC}	0.2	0.4	0.6	0.8	1.0	1.5	2.0	2.5	3.0	5.0	7.5	10.0	15.0
I_C													

$I_B = 40\ \mu A$

V_{CC}	0.2	0.4	0.6	0.8	1.0	1.5	2.0	2.5	3.0	5.0	7.5	10.0	15.0
I_C													

$I_B = 60\ \mu A$

V_{CC}	0.2	0.4	0.6	0.8	1.0	1.5	2.0	2.5	3.0	5.0	7.5	10.0	15.0
I_C													

BIPOLAR-JUNCTION TRANSISTOR CIRCUITS
UNIT VI

NAME________________________________

TEST

1. Match the terms on the right with their correct definitions.

_____a. The impedance of a circuit as viewed from its input terminals

_____b. Output voltage divided by input voltage

_____c. Output power divided by input power

_____d. The impedance of a circuit as viewed from the output terminals

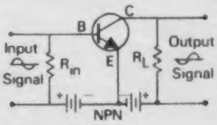
_____e. Output current divided by input current

_____f. Ratio of the output quantity to input quantity, often abbreviated as "A"

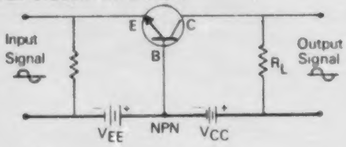
_____g. A ratio of an output level to an input level

1. Gain
2. Power gain
3. Current gain
4. Voltage gain
5. Input impedance
6. Output impedance
7. db

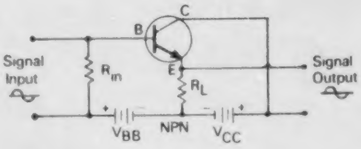
2. Identify the basic types of transistor circuits.


B
C
E
Input Signal
R_{in}
R_L
Output Signal
NPN

a ____________________


Input Signal
E
C
B
R_L
Output Signal
V_{EE}
NPN
V_{CC}

b. ____________________


Signal Input
B
C
E
R_{in}
R_L
Signal Output
V_{BB}
NPN
V_{CC}

c. ____________________

3. Match the transistor circuits on the right with the terms or values for circuit current gain.

_____a. h_{fe}

_____b. h_{fb}

_____c. Much greater than 1; typical current gain value = 50

_____d. Beta or β

_____e. Alpha or α

_____f. Called emitter follower

_____g. Current gain less than 1; typically 0.95 to 0.99

1. Common base
2. Common emitter
3. Common collector

4. Complete the following table to show the relative magnitudes of current, voltage, and power gain for basic transistor circuits.

Characteristics	Common Emitter	Common Base	Common Collector
Voltage Gain $A_V = \frac{V\ Out}{V\ In}$			
Current Gain $A_I = \frac{I\ Out}{I\ In}$			
Power Gain $A_P = \frac{P\ Out}{P\ In}$			

5. State which transistor circuit types give phase reversal by indicating yes or no by each.

a. CE ____________________

b. CB ____________________

c. CC ____________________

6. Match the transistor circuits on the right with their common applications.

_____a. Small signal amplification	1. CC
_____b. High frequency power amplification	2. CE
_____c. Voltage follower	3. CB

7. Complete the following table to show the relative magnitudes of input and output impedances for basic transistor circuits.

Characteristics	Common Emitter	Common Base	Common Collector
Input Impedance		Low	
Output Impedance	Medium		Low

8. Compute voltage, current, and power gain in decibels.

9. Demonstrate the ability to:

   a. Construct and test a common-emitter circuit.

   b. Construct and test a common-base circuit.

   c. Construct and test a common-collector circuit.

   d. Plot a transistor output characteristic curve.

   (NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

BIPOLAR JUNCTION TRANSISTOR CIRCUITS
UNIT VI

ANSWER TO TEST

1. a. 5 e. 3
   b. 4 f. 1
   c. 2 g. 7
   d. 6

2. a. Common emitter
   b. Common base
   c. Common collector

3. a. 2 e. 1
   b. 1 f. 3
   c. 2 g. 1
   d. 2

4.

Characteristics	Common Emitter	Common Base	Common Collector
Voltage Gain $A_V = \frac{V\,Out}{V\,In}$	High (300)	High (500)	Low Less Than One
Current Gain $A_i = \frac{I\,Out}{I\,In}$	High (50)	Less Than One (0.97)	High (50)
Power Gain $A_P = \frac{P\,Out}{P\,In}$	Very High (15,000)	Medium (400)	Low (30)

5. a. Yes
   b. No
   c. No

6. a. 2
   b. 3
   c. 1

7.

Characteristics	Common Emitter	Common Base	Common Collector
Input Impedance	Medium (1,000)	Low (60)	High (400,000)
Output Impedance	Medium (50,000)	High (1 M)	Low (100)

8. Evaluated to the satisfaction of the instructor

9. Performance skills evaluated to the satisfaction of the instructor

TRANSISTOR AMPLIFIERS
UNIT VII

UNIT OBJECTIVE

After completion of this unit, the student should be able to match terms associated with single-stage and multi-stage amplifiers, construct a load line, calculate overall amplifier gain in db, list the various coupling techniques, and construct and test various types of amplifier circuits. This knowledge will be evidenced by correctly performing the procedures outlined in the assignment and job sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to transistor amplifiers with their correct definitions.
2. Identify a voltage divider bias circuit.
3. Select true statements concerning leakage current.
4. Complete a table showing the classes of amplifiers, applications, and performance characteristics.
5. Select statements describing the characteristics of a Class B push-pull amplifier.
6. Select statements describing the characteristics of a Darlington-pair circuit.
7. Locate the Q point, saturation point, and cutoff point in a common emitter Class A amplifier circuit.
8. Complete a list showing the characteristics of different types of coupling.
9. Distinguish between ratio stage gains and dB stage gains in overall amplifier gain.
10. Select true statements concerning frequency considerations.
11. Construct a load-line for a common-emitter amplifier circuit.
12. Calculate the overall gain of multistage-amplifier circuits.
13. Demonstrate the ability to:
    a. Test a single-ended amplifier.
    b. Test a push-pull amplifier.
    c. Test a two stage direct coupled amplifier.
    d. Test a basic Darlington-pair amplifier.

TRANSISTOR AMPLIFIERS
UNIT VII

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information, assignment, and job sheets.

III. Make transparencies.

IV. Discuss unit and specific objectives.

V. Discuss information and assignment sheets.

VI. Demonstrate and discuss the procedures outlined in the job sheets.

VII. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

   A. Objective sheet

   B. Information sheet

   C. Transparency masters

      1. TM 1--Voltage Divider Bias Circuit
      2. TM 2--Amplifier Characteristics by Class of Operation
      3. TM 3--Class B Push-Pull Amplifier
      4. TM 4--Darlington Pair
      5. TM 5--Transistor Load Line
      6. TM 6--Coupling Methods
      7. TM 7--Frequency Compensation Networks

   D. Assignment sheets

      1. Assignment Sheet #1--Construct a Load Line for a Common-Emitter Amplifier Circuit
      2. Assignment Sheet #2--Calculate the Overall Gain of Multistage-Amplifier Circuits

E. Answer to assignment sheets

F. Job sheets

1. Job Sheet #1--Test a Single Ended Amplifier
2. Job Sheet #2--Test a Push-Pull Amplifier
3. Job Sheet #3--Test a Two Stage Direct Coupled Amplifier
4. Job Sheet #4--Test a Basic Darlington Pair Amplifier

G. Test

H. Answers to test

II. Reference--Faber, Rodney B. *Introduction to Electronic Amplifiers*. Columbus, OH: Merrill Publishing Co., 1971.

TRANSISTOR AMPLIFIERS
UNIT VII

INFORMATION SHEET

I. Terms and definitions

   A. Single-ended amplifier--An amplifier in which only one transistor is used in the amplifier stage

   B. Class A circuit--An amplifier biased so that the collector current flows during the entire input-signal cycle

   C. Class B circuit--An amplifier biased so that the collector current flows during half of the input-signal cycle

   D. Class C circuit--An amplifier biased so that the collector current flows for less than half of the input-signal cycle

   E. Push-pull amplifier--An amplifier which uses two transistors connected so that each transistor contributes current to the output signal on alternate half cycles of the input signal

   F. Darlington pair--An amplifier circuit in which two transistors are directly coupled in such a way as to provide impedance matching wide-band frequency response and high current gain

   G. Coupling--The methods used to connect the output of one stage of amplification to the input of another amplifier stage

   H. Leakage current--The current that flows through a reverse-bias transistor junction

   I. Efficiency--The ratio of AC power delivered to the load to the DC power taken from the power supply

   J. Crossover distortion--Distortion of the output of push-pull amplifier due to non-linear characteristics of the transistors

II. Voltage divider bias circuit (Transparency 1)

   A. Divides source voltage across a network of resistors

   B. Permits use of a selected portion of source voltage

III. Leakage current

   A. Types

      1. Common-base leakage current (I_{CBO})--With no emitter current

      2. Common-emitter leakage current (I_{CEO})--With no base current

INFORMATION SHEET

B. Problems

1. Ambient temperature rise increases leakage current
2. Leakage current rise increases junction temperature
3. Conditions given in parts 1 and 2 can cause thermal runaway which may result in the destruction of the transistor

C. Stabilizing resistor (Re in a common-emitter circuit)--Reduces the amount of voltage available at the input, which reduces the input-bias current and provides more stable operating conditions

IV. Classes of amplifiers, applications, and performance characteristics (Transparency 2)

Class	Application	Distortion	Efficiency
A	Audio-type amplifiers	Least	Least
B	Push-pull audio power amplifiers	Approximately same as Class A when operated in a push-pull configuration	Medium
C	High frequency applications and oscillators	Highest	Highest

(NOTE: Class B amplifiers conduct only during one half of the input signal cycle when operated in a single-ended configuration giving medium distortion.)

V. Class B push-pull amplifier (Transparency 3)

A. Requires two transistors

B. Reduces distortion (even and odd harmonic)

C. Increases load impedance

D. Increases output power

E. Each transistor conducts during one-half of the input cycle

F. Requires proper bias to eliminate crossover distortion

VI. Darlington-pair circuit (Transparency 4)

A. Direct coupled type of circuit

B. Used for impedance matching or in place of an impedance matching transformer

INFORMATION SHEET

C. Wide band frequency response

D. Voltage gain is less than one

E. High current gain

VII. Class A operation load line (Transparency 5)

A. Characteristic curves

1. I_C
2. V_{CE}
3. I_B

B. Saturation $I_{CMAX} = V_{CC}/R_L$

C. Cut off $I_C = 0; V_{CE} = V_{CC}$

D. Operating point or Q point for Class A amplifier

VIII. Characteristics of different types of coupling

A. Resistance-capacitance (RC) coupling (Transparency 6)

1. Broad frequency response
2. Economical
3. Small physical size
4. Provides dc isolation
5. Limits low frequency response

B. Impedance coupling (Transparency 6)

1. Amplifier output is larger at high frequencies than at low frequencies
2. Used when a narrow band of frequencies or a single frequency is to be amplified

C. Transformer coupling (Transparency 6)

1. Used in power stages
2. Used for impedance matching
3. More costly than RC coupling
4. Requires more space and is heavier
5. Excellent dc isolation between stages

D. Direct coupling

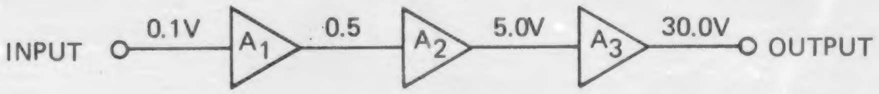
  1. Used for very low frequency or dc
  2. Used to couple only a few stages because of noise and signal amplification
  3. Widely used for a Darlington-pair amplifier

IX. Overall amplifier gain

A. Ratio stage gains--Multiply

B. dB stage gains--Add

Example: (calculation - Av):



Ratio-- $A_1 = 5$, $A_2 = 10$, $A_3 = 6$; $(A_1)(A_2)(A_3) = A_V$ Total = 300

dB-- $A_1 = 13.98\text{dB}$, $A_2 = 20\text{dB}$, $A_3 = 15.56\text{dB}$

or $A_V\text{db} = 20 \log 300 \quad 49.54\text{dB}$

$A_1 + A_2 + A_3 = A_V\text{dB}$ Total = 49.54dB

X. Frequency considerations

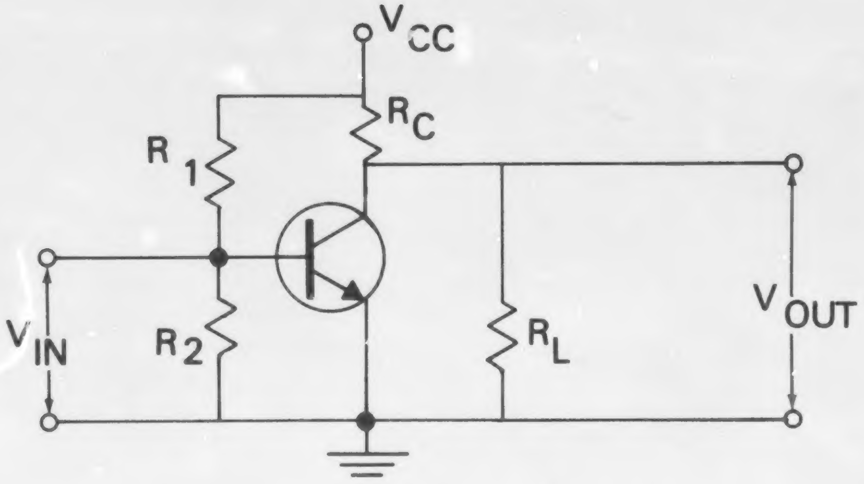
A. Low frequency response of an amplifier is limited by circuit series capacitance or shunt inductance

B. High frequency response of an amplifier is limited by circuit shunting capacitance or series inductance

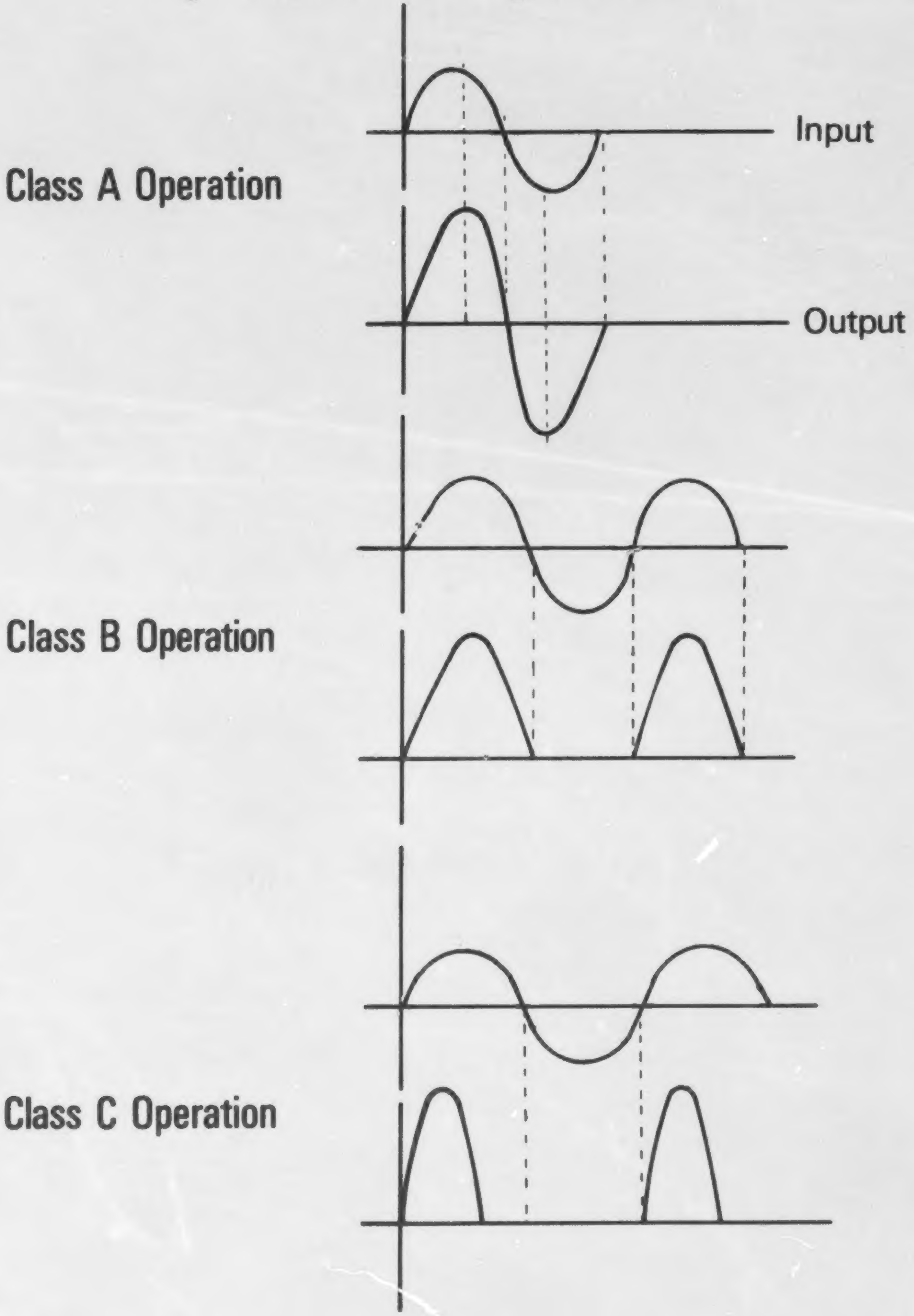
C. Frequency compensation networks (Transparency 7)

  1. High frequency compensation
  2. Low frequency compensation

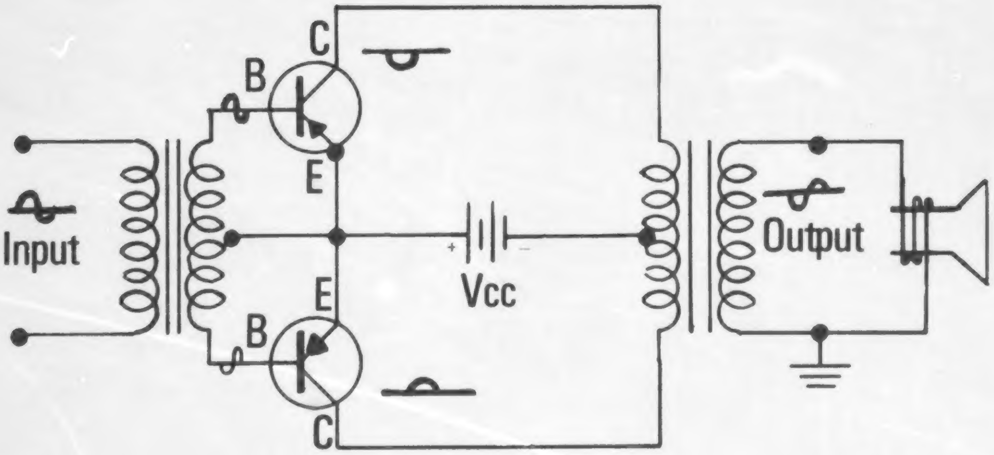
Voltage Divider Bias Circuit


V_{CC}
R_C
R_1
V_{IN}
R_2
R_L
V_{OUT}

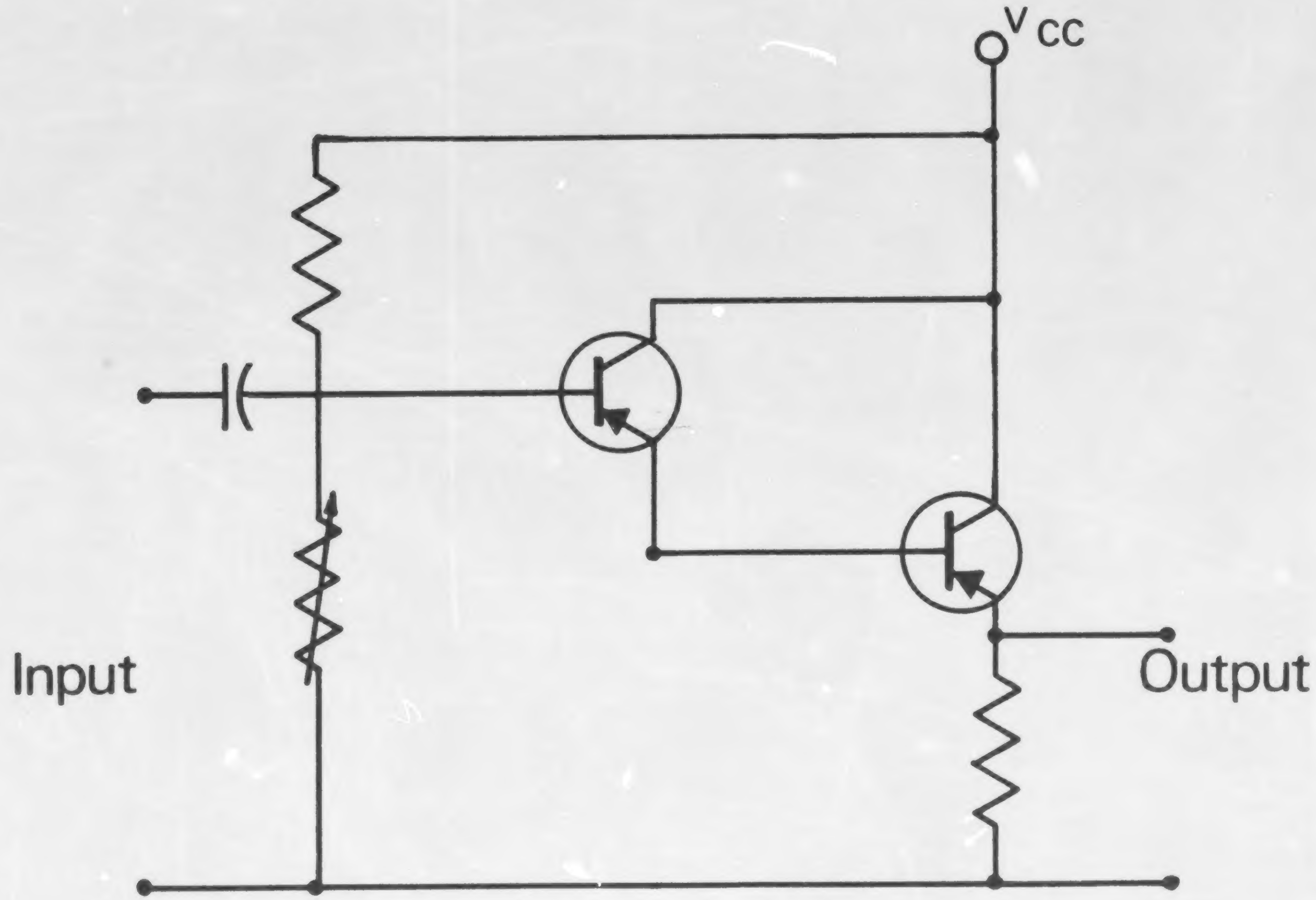
Amplifier Characteristics by Class of Operation


Input
Output
Class A Operation
Class B Operation
Class C Operation

Class B Push-Pull Amplifier

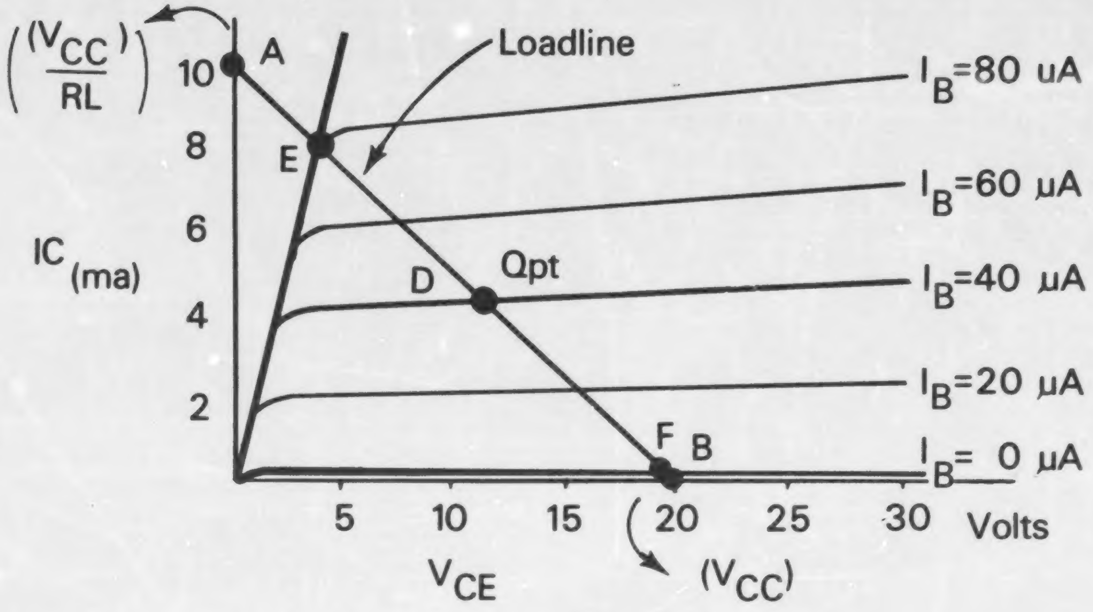

C
B
E
Input
E
B
C
Vcc
+
−
Output

Darlington Pair


V CC
Input
Output

Transistor Load Line

(Class A Operation)



Procedure

A. Locate maximum current point

$$\frac{V_{CC}}{RL} = I_{max}$$

B. Locate maximum voltage point

$$V_{CE} = V_{CC}$$

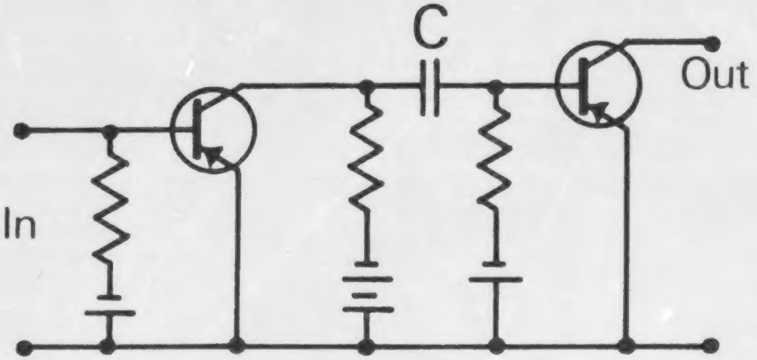
C. Connect these two points with a straight line

D. Locate operating point, Q point, by the intersection of the I B line with the load line

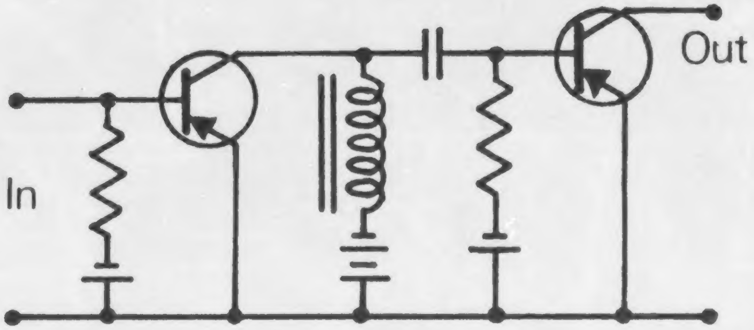
E. Saturation point

F. Cut off point

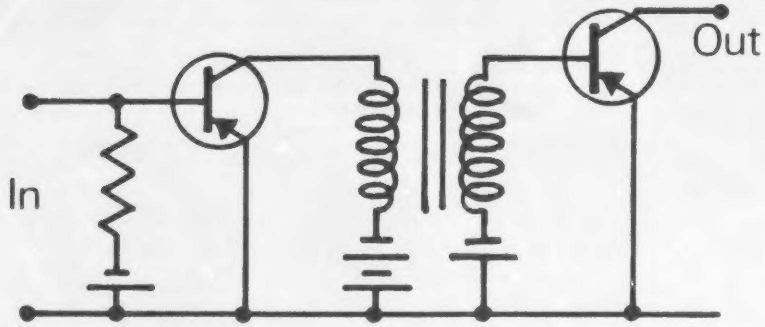
Coupling Methods



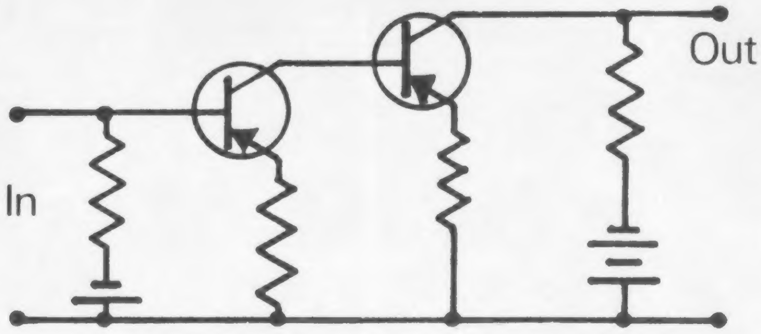
RC Coupling



Impedance Coupling

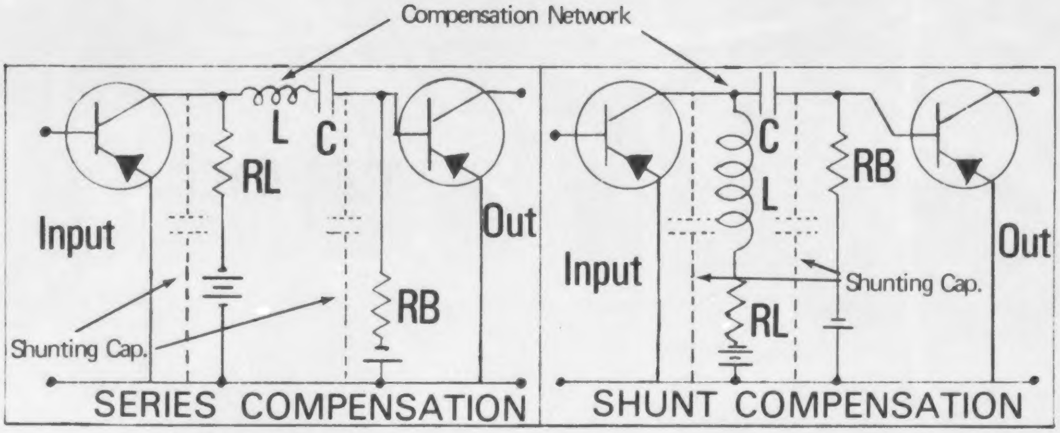


Transformer Coupling

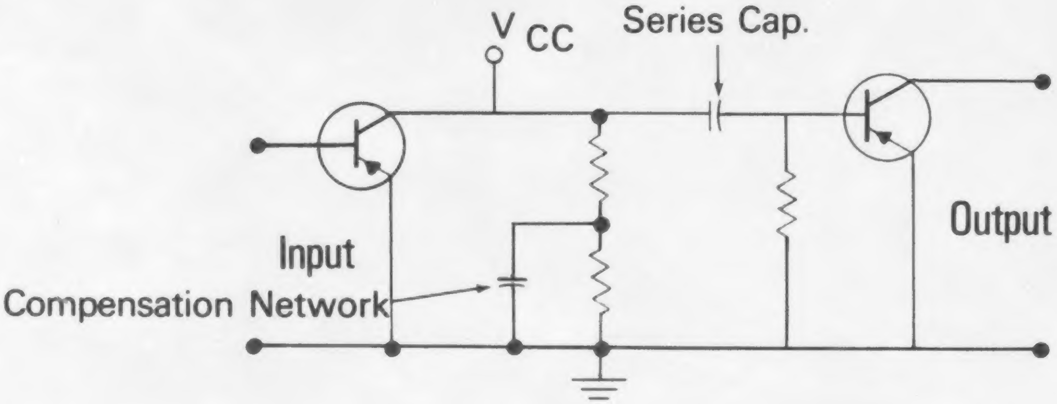


Direct Coupling

Frequency Compensation Networks


Compensation Network
L
C
RL
RB
Input
Out
Shunting Cap.
SERIES COMPENSATION
C
L
RB
RL
Input
Out
Shunting Cap.
SHUNT COMPENSATION

High Frequency Compensation


V CC
Series Cap.
Input
Output
Compensation Network

Low Frequency Compensation

TRANSISTOR AMPLIFIERS
UNIT VII

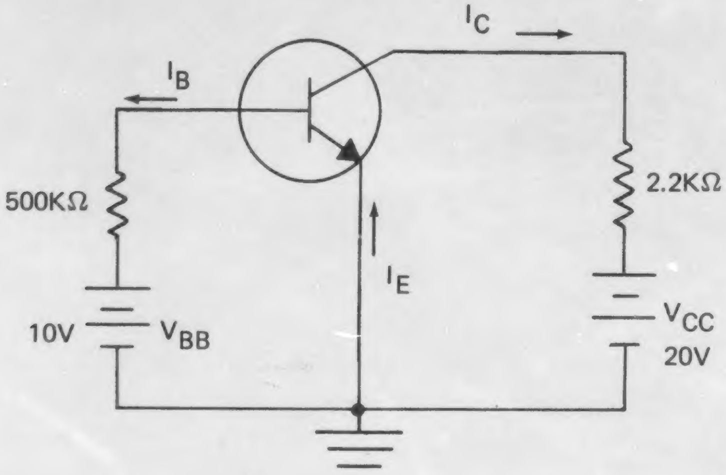
ASSIGNMENT SHEET #1--CONSTRUCT A LOAD LINE FOR A COMMON-EMITTER AMPLIFIER CIRCUIT

Direction: Construct a load-line for the transistor circuit shown below and locate the following points:

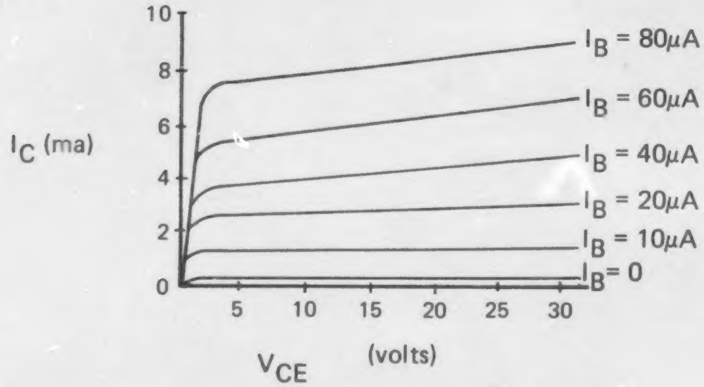
A. Q point (operating point)

B. Saturation point

C. Cutoff point



I_C
I_B
500KΩ
2.2KΩ
I_E
10V
V_{BB}
V_{CC}
20V

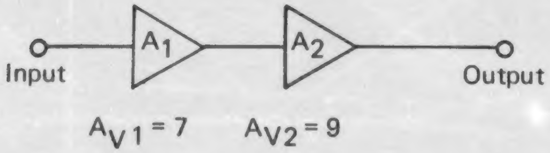


TRANSISTOR AMPLIFIERS
UNIT VII

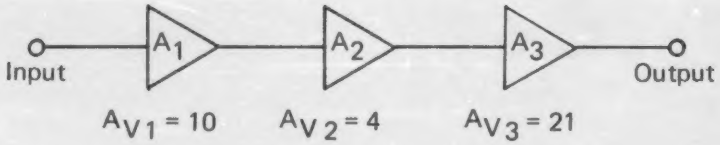
ASSIGNMENT SHEET #2--CALCULATE THE OVERALL GAIN OF MULTISTAGE-AMPLIFIER CIRCUITS

Directions: Given the amplifier block diagrams below, calculate the overall gain and express in dB.

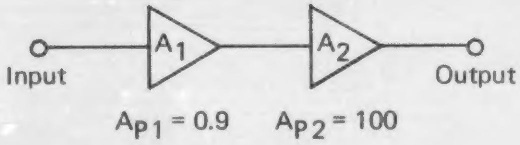
A.


Input
A_1
A_2
Output
$A_{V1} = 7$
$A_{V2} = 9$

B.


Input
A_1
A_2
A_3
Output
$A_{V1} = 10$
$A_{V2} = 4$
$A_{V3} = 21$

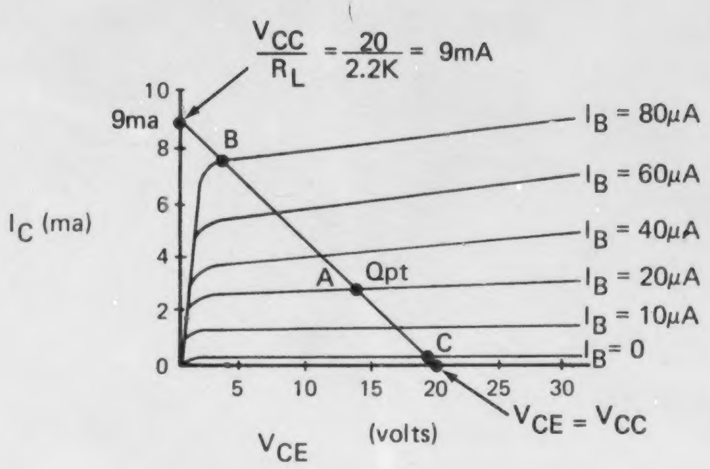
C.


Input
A_1
A_2
Output
$A_{P1} = 0.9$
$A_{P2} = 100$

TRANSISTOR AMPLIFIERS
UNIT VII

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1



$\frac{V_{CC}}{R_L} = \frac{20}{2.2K} = 9mA$

A. Qpt =
B. Saturation point
C. Cut off point

$I_B = \frac{10V}{500K} = 20\mu A$

Assignment Sheet #2

1. Av total = 35.99db

   A_{V1} (7) x A_{v2}(9) = 63

   A_vdB = 20 log 63

2. $A_{v_1} = 10$ $A_{v2} = 4$ Av 3 = 21

   A_v Total = 10 x 4 x 21 = 840

   A_v Total db = 20 log 840 = 58.49

3. $A_{p_1} = 0.9$ $Ap_2 = 100$ =   90

   A_{p_1} dB = -.46 Ap_2 = 20db   =   19.54

   A_v Total = (0.9) (100) = 90

   A_v Total dB = (10 log .9) = 10 log 100
   -.46   +   20   =   19.54

TRANSISTOR AMPLIFIERS
UNIT VII

JOB SHEET #1--TEST A SINGLE-ENDED AMPLIFIER

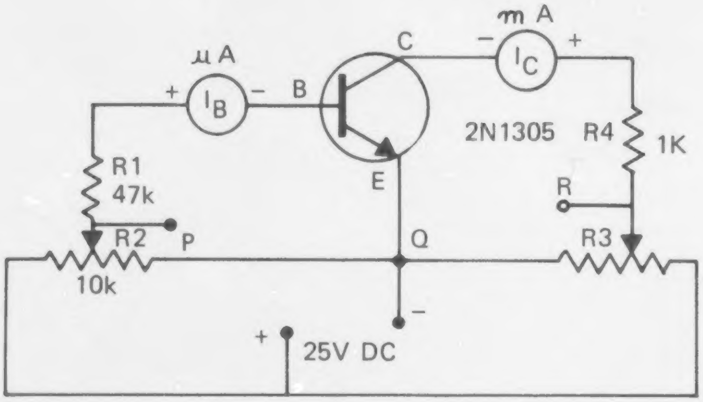
I. Tools and equipment

- A. 1-2N2222 transistor
- B. 1-47k resistor
- C. 1-1k resistor
- D. Microammeter and 1 milliammeter (or two multimeters)
- E. 1-22k resistor
- F. 1-220k resistor
- G. 1-1.5k resistor
- H. 1-4.7k resistor
- I. DC power supply (0-25V)
- J. Soldering iron or soldering gun

  (NOTE: All resistors are ± watt.)
- K. 1-1k potentiometer
- L. 1-10V potentiometer

II. Procedure

- A. Wire the circuit shown below



JOB SHEET #1

B. Adjust potentiometer R_2 so that the voltage between points Q and P is zero

C. Plug in soldering iron or gun

D. After instructor approves wiring, turn on the power; then adjust R3 for 18 volts between points Q and R

E. Adjust R2 to 50 microamps of base current, I_B

(NOTE: It may be necessary to readjust R_3 for 18 volts.)

F. Record the value of collector current, I_C

G. Hold hot soldering gun or iron near the transistor case for three seconds

H. Record the maximum value of the collector current

I. Remove iron and wait until the collector current is approximately the same value as that recorded in Step D

J. Remove power and insert a 1.5k resistor (R_e) between the emitter and ground

K. Apply power and readjust R2 to 50 microamps base current

(NOTE: It may be necessary to readjust R_3 for 18 volts.)

L. Read and record the collector current

M. Repeat steps G and I

N. Remove power and replace 1.5k with a 4.7k resistor

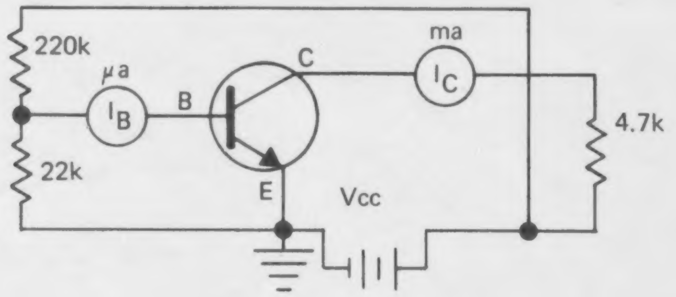
O. Repeat Steps G and I

P. Calculate the changes in collector current, I_C, for each of the three conditions as shown in the table below

R_E	I_B	I_C (cool)	I_C (hot)	ΔI_C
O				
1.5k				
4.7k				

JOB SHEET #1

Q. Turn off the power supplies and rewire circuit as shown below



R. After instructor has checked the wiring, turn on the power supply and set it for an output of 15 volts

S. Read and record I_B and I_C

T. Hold the soldering gun or iron close to the transistor and heat it for 3 seconds

U. Read and record the maximum value of I_C

V. Remove power and leave one end of the 220k-ohm resistor connected to the base

W. Remove the other end from the power supply and connect it to the collector of the transistor

X. Apply power and read and record I_B and I_C

Y. Hold the soldering gun close to the transistor and heat it for 3 seconds

Z. Read and record the maximum value of I_C

AA. Compute the change observed in I_C in these two circuits and record in the table below

	I_B	I_C (cool)	I_C (hot)	ΔI_C
Voltage Divider across V_{CC}				
Collector Feedback				

BB. Check completed tables with your instructor

TRANSISTOR AMPLIFIERS
UNIT VII

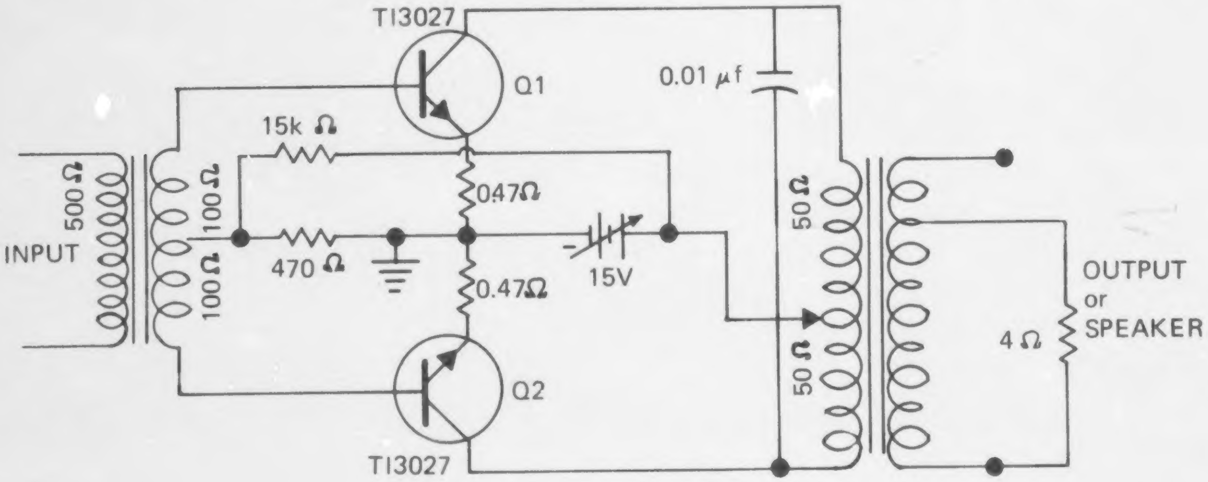
JOB SHEET #2--TEST A PUSH-PULL AMPLIFIER

I. Tools and equipment

- A. 2 power transistors (TI3027 or equivalent)
- B. Input transformer (500 ohm primary -- 200 ohm center-tapped secondary)
- C. Output transformer (100 ohm CT -- 4 ohm)
- D. 1-15k resistor, 1/2 watt
- E. 1-470 ohm resistor, 1/2 watt
- F. 1-4 ohm resistor, 2 W
- G. 1-0.47 ohm resistor, 2 W
- H. AF signal generator
- I. Oscilloscope
- J. Graph paper
- K. 0.01 µfd capacitor
- L. Power supply
- M. Multimeter

II. Procedure

- A. Wire the circuit shown in the following schematic with power off


TI3027
Q1
0.01 µf
15k Ω
500 Ω
INPUT
100 Ω
100 Ω
047Ω
470 Ω
0.47Ω
15V
50 Ω
50 Ω
OUTPUT
or
SPEAKER
4 Ω
Q2
TI3027

JOB SHEET #2

B. Have instructor approve wiring, then turn on the power supply and adjust for 15 volts

C. Measure and record the base-emitter bias voltages V_{BE} of Q1 and Q2

D. Compute the DC-emitter currents using Ohm's Law by measuring the voltage drops across the 0.47 ohm resistors

E. Connect the audio generator to the input transformer and set the output of the generator to 1000 Hz

F. Connect the oscilloscope across the 4-ohm load on the secondary of the output transformer and adjust the signal generator for maximum undistorted output as read on the oscilloscope and sketch the waveshape

G. Connect the oscilloscope across the input and make a scale drawing of the scope display

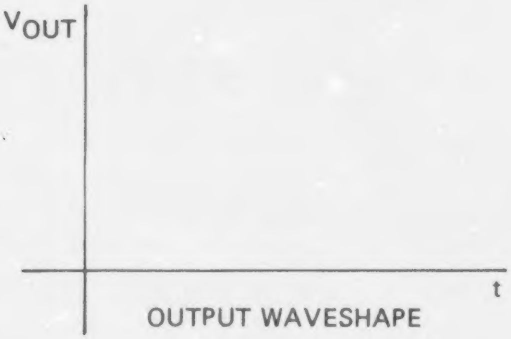
H. Connect the oscilloscope across the base-emitter junction of Q1 and sketch the waveshape

I. Repeat for Q2

J. Check calculations and drawings with your instructor

Data Table

	V_{BE}	I_E	$V_{OUT\ P-P}$	$V_{IN\ P-P}$
Q_1				
Q_2				



OUTPUT WAVESHAPE

INPUT WAVESHAPE

TRANSISTOR AMPLIFIERS
UNIT VII

JOB SHEET #3--TEST A TWO STAGE DIRECT COUPLED AMPLIFIER

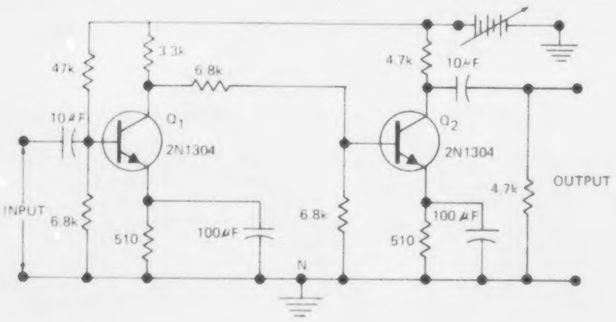
I. Tools and equipment

- A. 2-2N1304 transistors or equivalent
- B. 2-10 μF capacitors (20V)
- C. 2-100 μF capacitors (20V)
- D. 1-47k resistor (1/2 watt)
- E. 3-6.8k resistors, 1/2W
- F. 2-4.7k resistors, 1/2W
- G. 1-3.3k resistor, 1/2W
- H. 2-510 ohm resistors, 1/2W
- I. Variable DC power supply (0-20V)
- J. Oscilloscope
- K. Signal generator
- L. Graph paper
- M. D.C. voltmeter

II. Procedure

A. Connect the following circuit with power off

(NOTE: A voltage divider is used between the two stages to provide the necessary bias for the second stage.)


47k
3.3k
6.8k
4.7k
10μF
10μF
Q1
2N1304
Q2
2N1304
INPUT
6.8k
510
100μF
N
6.8k
510
100 μF
4.7k
OUTPUT

JOB SHEET #3

B. Connect the oscilloscope across the 4.7k output resistor

C. Connect the signal generator to the input terminals and adjust the frequency for 1000Hz; leave the voltage level at zero

D. Adjust the power supply for 15 volts and measure and record the voltages with respect to ground on the emitter, base, and collector of the two transistors

E. Adjust the signal generator until an undistorted waveshape appears on the oscilloscope

(NOTE: All voltage measurements should be referenced to ground.)

F. Measure and record the peak-to-peak output voltage using the oscilloscope and sketch the waveshape

G. Measure and record the peak-to-peak input voltage at the base of the second transistor

H. Measure and record the peak-to-peak output voltage at the collector of the first stage

I. Measure and record the peak-to-peak input voltage at the base of the first stage

J. Determine the voltage gain of the first stage and convert the voltage gain to a dB gain

K. Determine the voltage gain of the second stage and convert the voltage gain to dB gain

L. Determine the overall voltage gain and convert the voltage gain to dB gain

M. Connect the oscilloscope on the input (base) to the first stage and adjust the signal generator for the maximum undistorted signal at 10KHz.

(NOTE: The input signal voltage must be maintained at a constant level.)

N. Measure and sketch the voltage across the output resistor

O. Adjust the signal generator for the following frequencies and record the input and output voltage for each frequency: 10,000, 8000, 6000, 4000, 2000, 1000, 800, 600, 400, and 200 Hz.

P. Plot a graph of the output voltage versus the frequency; the frequency should be plotted on the horizontal axis and the voltage on the vertical axis

Q. Check calculations and sketches with your instructor

JOB SHEET #3

Data Table

	V_{BE}	V_{CE}	V_{EN}	$V_{OUT\ P\text{-}P}$	$V_{IN\ P\text{-}P}$	$V_{OUT\ P\text{-}P}$	$V_{IN\ P\text{-}P}$	A_V	A_{VdB}
Q_1				╳	╳				
Q_2						╳	╳		

$A_{V_{TOTAL}}$ = ________________ dB

	$10KH_z$	$8KH_z$	$6KH_z$	$4KH_z$	$2KH_z$	$1KH_z$	$800K_z$	$600H_z$	$400H_z$	$200H_z$
$V_{IN\ P\text{-}P}$										
$V_{OUT\ P\text{-}P}$										

TRANSISTOR AMPLIFIERS
UNIT VII

JOB SHEET #4--TEST A BASIC DARLINGTON-PAIR AMPLIFIER

I. Tools and equipment

   A. 2-PNP transistors (2N3638 or equivalent)

   B. 1-10 μF capacitor (25V)

   C. 1-3 M resistor, 1/2W

   D. 1-1 k resistor, 1W

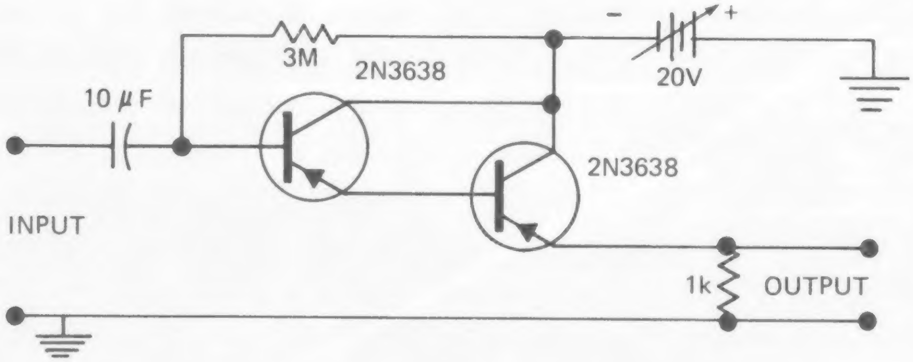
   E. Oscilloscope

   F. Signal generator

   G. Power supply (0-40V, DC)

II. Procedure

   A. Wire the following circuit with power off



   B. Connect the oscilloscope to the output of the signal generator and the signal generator to the circuit input

   C. Set the generator for 1000 Hertz and adjust until 4 volts peak-to-peak is on the oscilloscope screen

   D. Place the generator leads to the Darlington circuit input leads, and leave the oscilloscope still connected to the generator output

   E. Move the oscilloscope leads from the input to the output and measure the output voltage (peak-to-peak)

INFORMATION SHEET

F. Compute the overall voltage gain in dB

G. Check your calculations with your instructor

Data Table

$V_{IN\ P\text{-}P}$	$V_{OUT\ P\text{-}P}$

A_{VdB} = ____________

TRANSISTOR AMPLIFIERS
UNIT VII

NAME ______________________________

TEST

1. Match the terms on the right with their correct definitions.

______ a. The current that flows through a reverse-bias transistor junction

______ b. An amplifier which uses two transistors connected so that each transistor contributes current to the output signal on alternate half cycles of the input signal

______ c. An amplifier biased so that the collector currect flows for less than half of the input-signal cycle

______ d. An amplifier in which only one transistor is used in the amplifier stage

______ e. The methods used to connect the output of one stage of amplification to the input of another amplifier stage

______ f. The ratio of AC power delivered to the load to the DC power taken from the power supply

______ g. An amplifier biased so that the collector current flows during the entire input-signal cycle

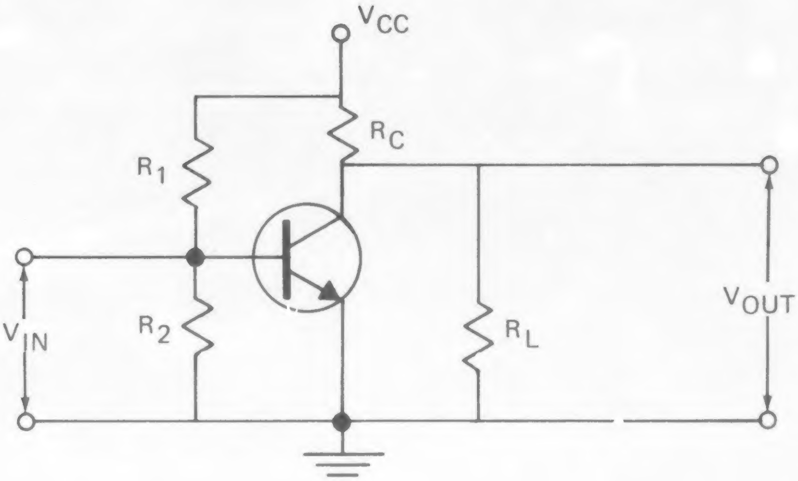
______ h. An amplifier biased so that the collector current flows during half of the input-signal cycle

______ i. An amplifier circuit in which two transistors are directly coupled in such a way as to provide impedance matching wide-band frequency response and high current gain

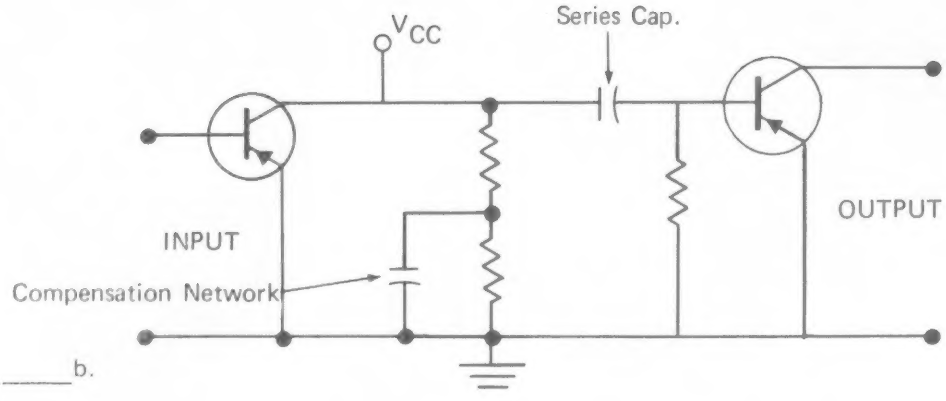
______ j. Distortion of the output of the push-pull amplifier due to non-linear characteristics of the transistors

1. Leakage current
2. Single-ended amplifier
3. Class A circuit
4. Darlington pair
5. Push-pull amplifier
6. Coupling
7. Class B circuit
8. Class C circuit
9. Efficiency
10. Crossover distortion

2. Identify the voltage divider bias circuit by placing an "X" under the appropriate circuit.


V_{CC}
R_C
R_1
R_2
V_{IN}
R_L
V_{OUT}

_____ a.


V_{CC}
Series Cap.
INPUT
OUTPUT
Compensation Network

_____ b.

3. Select true statements concerning sources of leakage current and problems associated with it by placing an "X" in the appropriate blanks.

_____a. I_{CBO} is a type of leakage with no emitter current

_____b. I_{CEO} is a type of leakage with no base current

_____c. Ambient temperature rise increases leakage current

_____d. Leakage current rise increases junction temperature

_____e. Conditions given in parts c and d above can cause thermal runaway which may result in the destruction of the transistor

_____f. The stabilizing resistor increases the amount of voltage available at the input, which reduces the input-bias current and provides more stable operating conditions

4. Complete the following table showing the classes of amplifiers, applications, and performance characteristics.

Class	Application	Distortion	Efficiency
A	Audio-type amplifiers		
B	Push-pull audio power amplifiers		
C	High frequency applications and oscillators		

5. Select true statements describing the characteristics of a Class B push-pull amplifier by placing an "X" in the appropriate blanks.

_____a. Requires only one transistor

_____b. Requires two transistors

_____c. Reduces distortion

_____d. Decreases output power

_____e. Each transistor conducts during one-half the input cycle

_____f. Requires proper bias to eliminate crossover distortion

6. Select true statements describing the characteristics of a Darlington-pair circuit by placing an "X" in the appropriate blanks.

______ a. Capacitance coupled between stages

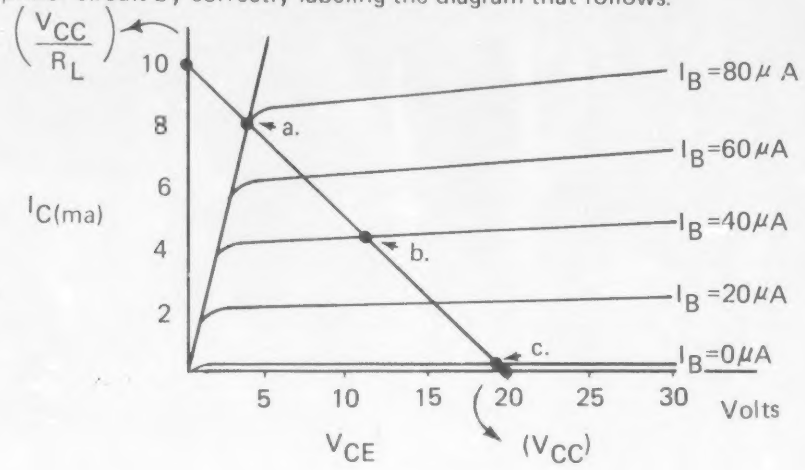
______ b. Direct coupled type of circuit

______ c. Narrow band frequency response

______ d. Voltage gain is less than one

______ e. High current gain

7. Locate the Q point, saturation point, and cutoff point in a common-emitter Class A amplifier circuit by correctly labeling the diagram that follows.



a. ____________________ b. ____________________ c. ____________________

8. Complete a list showing the characteristics of different types of coupling by placing the correct information in the blanks below each of the following headings.

a. Resistance-capacitance coupling

1) ____________________

2) Economical

3) Small physical size

4) Provides dc isolation

5) Limits low frequency response

b. Impedance coupling

1) ____________________

2) Used when a narrow band of frequencies or a single frequency is to be amplified

c. Transformer coupling
  1) Used in power stages
  2) Used for impedance matching
  3) More costly than RC coupling
  4) Requires more space and is heavier
  5) ____________________

d. Direct coupling
  1) Used for very low frequency or dc
  2) Used to couple only a few stages because of noise and signal amplification
  3) ____________________

9. Distinguish between ratio stage gains and db stage gains in overall amplifier gain by placing an "R" next to material that applies to ratio gains and "dB" beside material that applies to dB gain.

_____a. Multiply

_____b. Add

10. Select true statements concerning frequency considerations by placing an "X" in the appropriate blanks.

_____a. Low frequency response of an amplifier is limited by circuit series capacitance or shunt inductance

_____b. High frequency response of an amplifier is limited by circuit series capacitance or series inductance

_____c. Frequency compensation networks include
  1) High frequency compensation
  2) Low frequency compensation

11. Construct a load-line for a common-emitter amplifier circuit.

12. Calculate the overall gain of multistage-amplifier circuits.

13. Demonstrate the ability to:
  a. Test a single-ended amplifier
  b. Test a push-pull amplifier
  c. Test a two stage direct coupled amplifier

d. Test a basic Darlington-pair amplifier

(NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

TRANSISTOR AMPLIFIERS
UNIT VII

ANSWERS TO TEST

1. a. 1
   b. 5
   c. 8
   d. 2
   e. 6
   f. 9
   g. 3
   h. 7
   i. 4
   j. 10

2. a

3. a, b, c, d, e

4.

Class	Application	Distortion	Efficiency
A	Audio-type amplifiers	Least	Least
B	Push-pull audio power amplifiers	Approximately same as Class A when operated in a push-pull configuration	Medium
C	High frequency applications and oscillators	Highest	Highest

5. b, c, e, f

6. b, d, e

7. a. Saturation point
   b. Q point
   c. Cutoff point

8. a. 1) Broad frequency response
   b. 1) Amplifier output is larger at high frequencies than at low frequencies
   c. 5) Excellent dc isolation between stages
   d. 3) Widely used for a Darlington-pair amplifier

9. a. R
   b. dB

10. a, c

11. Evaluated to the satisfaction of the instructor

12. Evaluated to the satisfaction of the instructor

13. Performance skills evaluated to the satisfaction of the instructor

OPERATIONAL AMPLIFIERS
UNIT VIII

UNIT OBJECTIVE

After completion of this unit, the student should be able to identify the categories and subdivisions of integrated circuits, list advantages and disadvantages of integrated circuits, calculate gain for various types of operational amplifiers, and construct and test various types of operational amplifier circuits. This knowledge will be evidenced by correctly performing the procedures outlined in the assignment and job sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to operational amplifiers with their correct definitions.
2. Complete a diagram to show the categories and subdivisions of integrated circuits.
3. Distinguish between the advantages and disadvantages of integrated circuits.
4. Match inverting and noninverting operational amplifiers with their characteristics and A_v formulas.
5. Match DC summing inverting and differential amplifiers with their characteristics and V_{out} formulas.
6. Calculate the closed-loop gain for an inverting and a noninverting amplifier.
7. Calculate the output voltage of a DC summing inverting amplifier.
8. Demonstrate the ability to:
    a. Construct and test an inverting amplifier.
    b. Construct and test a noninverting amplifier.
    c. Construct and test a DC summing inverting amplifier.
    d. Construct and test a differential amplifier.

OPERATIONAL AMPLIFIERS
UNIT VIII

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information, assignment, and job sheets.

III. Make transparencies.

IV. Discuss unit and specific objectives.

V. Discuss information and assignment sheets.

VI. Demonstrate and discuss the procedures outlined in the job sheets.

VII. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

   A. Objective sheet

   B. Information sheet

   C. Transparency masters

      1. TM 1--Categories of Integrated Circuits
      2. TM 2--Monolithic Integrated Circuit
      3. TM 3--Hybrid Thick Film Circuit
      4. TM 4--Inverting and Noninverting Amplifiers
      5. TM 5--DC Summing Inverting Amplifier
      6. TM 6--Differential DC Amplifier

   D. Assignment sheets

      1. Assignment Sheet #1--Calculate the Closed-Loop Gain for an Inverting and a Noninverting Amplifier
      2. Assignment Sheet #2--Calculate the Output Voltage of a DC Summing Inverting Amplifier

   E. Answers to assignment sheets

F. Job sheets

1. Job Sheet #1--Construct and Test an Inverting Amplifier
2. Job Sheet #2--Construct and Test a Noninverting Amplifier
3. Job Sheet #3--Construct and Test a DC Summing Inverting Amplifier
4. Job Sheet #4--Construct and Test a Differential Amplifier

G. Test

H. Answers to test

II. References

A. Seippel, Robert G. *Designing Circuits with IC Operational Amplifiers.* New York: American Technical Society, 1975.

B. Rutkowski, George B. *Handbook of Integrated Circuit Operational Amplifiers.* Englewood Cliffs, NJ: Prentice-Hall Inc., 1975.

OPERATIONAL AMPLIFIERS
UNIT VIII

INFORMATION SHEET

I. Terms and defintions

A. Integrated circuit (IC)--A complete electronic circuit that is fabricated on a single chip of silicon

B. Operational amplifier (OP-AMP)--A solid-state integrated circuit amplifier that uses external feedback to control its gain

C. Linear IC--A classification of integrated circuits used for analog amplification purposes

D. Digital IC--A classification of integrated circuits used for switching purposes

E. Monolithic device--A complete circuit including active and passive devices and all interconnections fabricated upon a single piece of silicon crystal material

F. Hybrid device--A device which is made by mounting separate components (resistors, transistors, and other devices) onto a substrate of insulating material such as glass or ceramic

G. Open-loop operation--An application of an operational amplifier circuit that uses no external feedback

H. Closed-loop operation--An application of an operational amplifier circuit that uses external feedback

II. Categories and subdivsions of integrated circuits (Transparency 1)

A. Monolithic--One method of IC fabrication (Transparency 2)

1. Bipolar--Diode and transistors

2. Unipolar--MOSFET and JFET device

B. HYBRID--One method of IC fabrication

1. Thick film--Components are approximately 100 times thicker than thin film (Transparency 3)

2. Thin film--Components are a few angstroms thick (Angstrom unit, $A^o = 10^{-8}$ cm)

INFORMATION SHEET

III. Advantages and disadvantages of integrated circuits

- A. Advantages
  - 1. Small size
  - 2. Low cost
  - 3. High reliability
- B. Disadvantages
  - 1. Limited to low voltage applications
  - 2. Limited to low power applications
  - 3. Limited component selection

IV. Characteristics and A_v formulas for inverting and noninverting operational amplifiers

- A. Inverting amplifier (Transparency 4)
  - 1. Output is 180° out of phase with the input
  - 2. $A_v = \frac{-R_2}{R_1}$
- B. Noninverting amplifier (Transparency 4)
  - 1. Input is in phase with the output
  - 2. $Av = \frac{R_1 + R_2}{R_1}$

V. Characteristics and V_{out} formulas for DC summing inverting amplifier and differential amplifiers

- A. DC summing inverting amplifiers (Transparency 5)
  - 1. Output is the sum of the input voltages with a 180° phase shift
  - 2. $V_{out} = -R_4\left(\frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3}\right)$

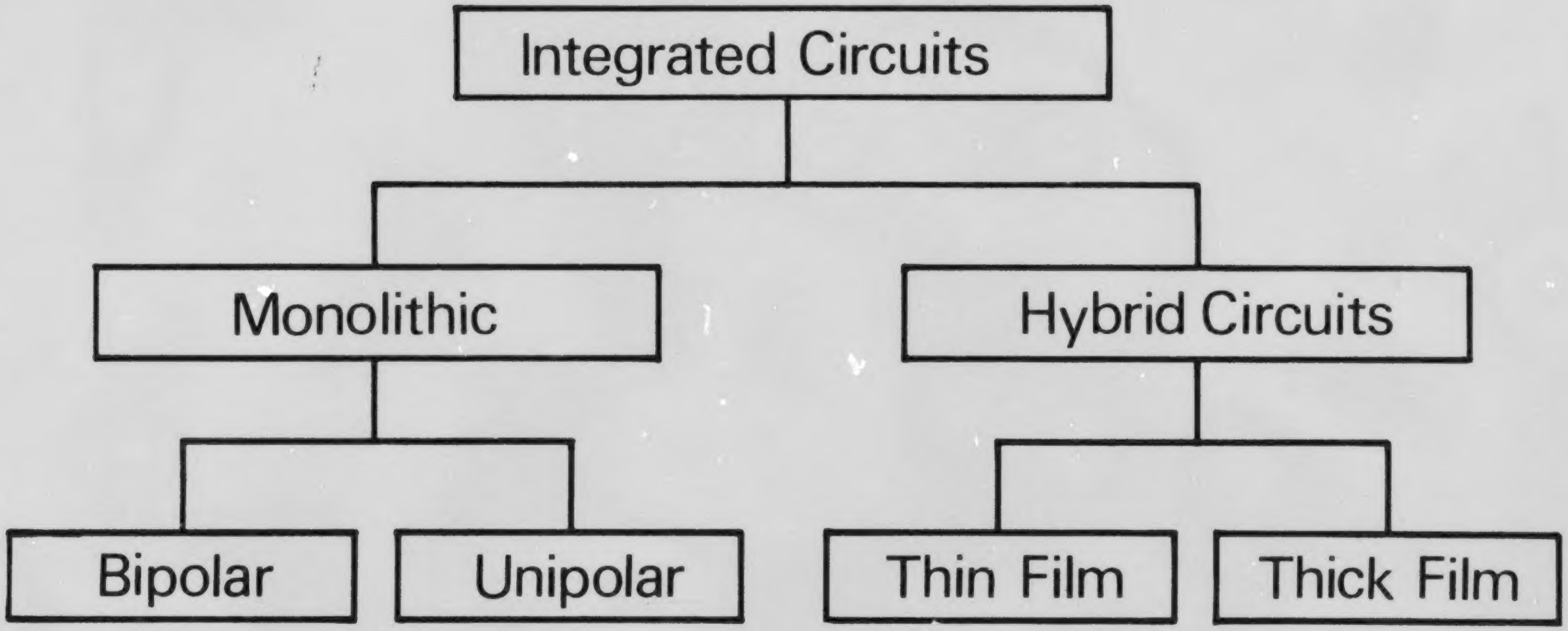
INFORMATION SHEET

B. Differential amplifiers (Transparency 6)

1. Output is a function of the difference between the two input signals

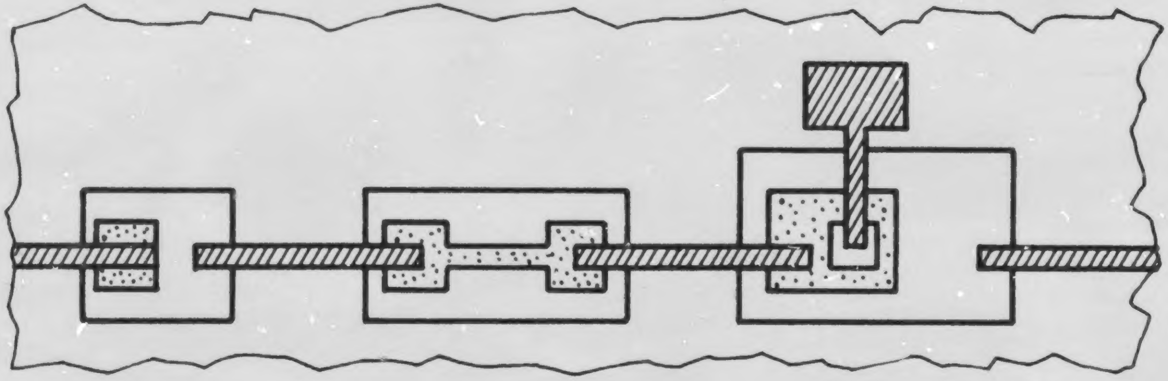
2. $V_{out} = \frac{R_2}{R_1}(V_2 - V_1)$; $R_1 = R_3$, $R_2 = R_4$

Categories of Integrated Circuits

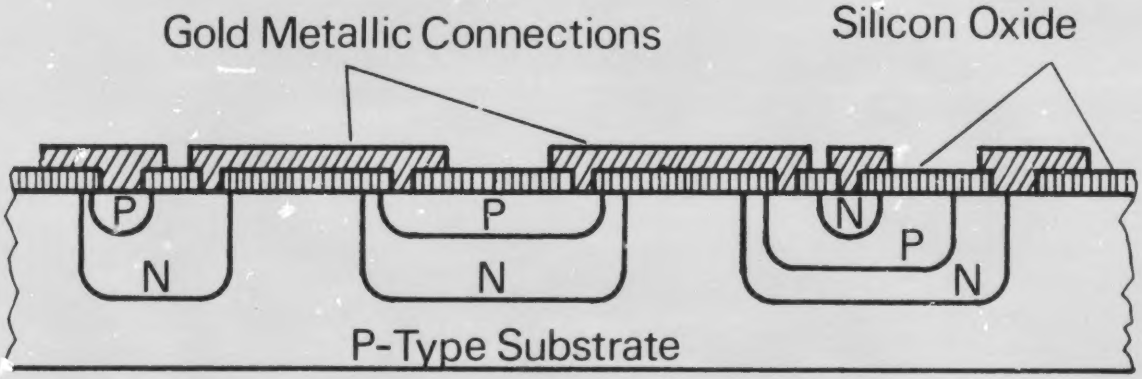


- Integrated Circuits
  - Monolithic
    - Bipolar
    - Unipolar
  - Hybrid Circuits
    - Thin Film
    - Thick Film

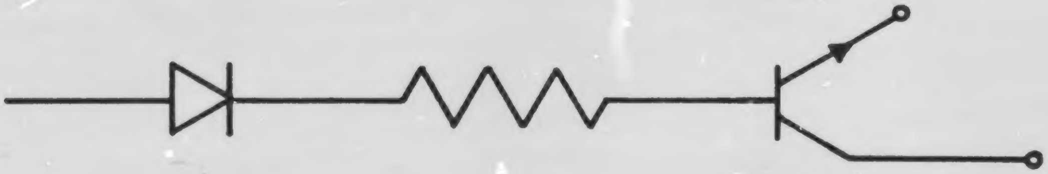
Monolithic Integrated Circuit



Top View (oxide omitted)

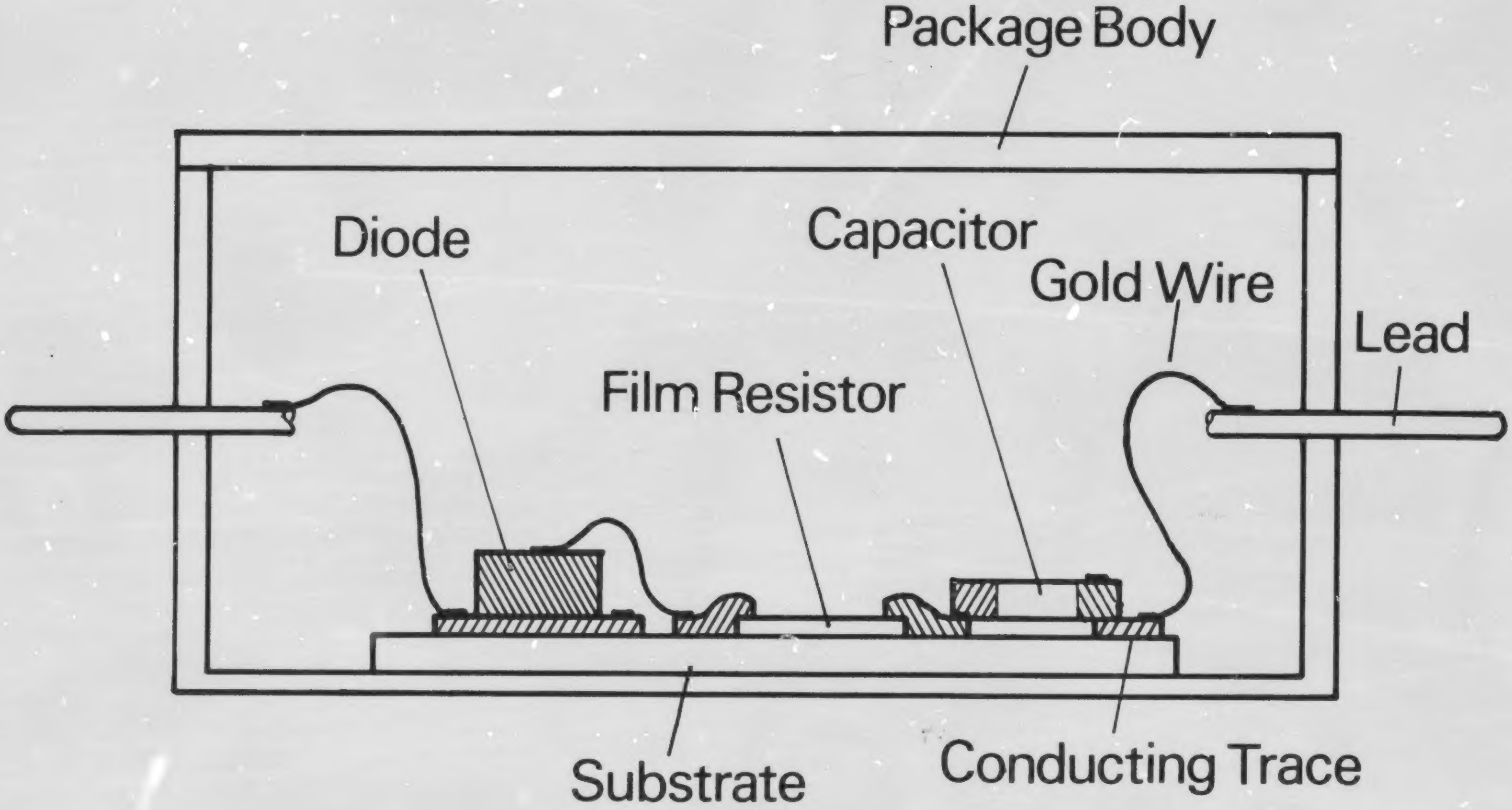

Gold Metallic Connections
Silicon Oxide
P
N
P
N
N
P
N
P-Type Substrate

Cross Section

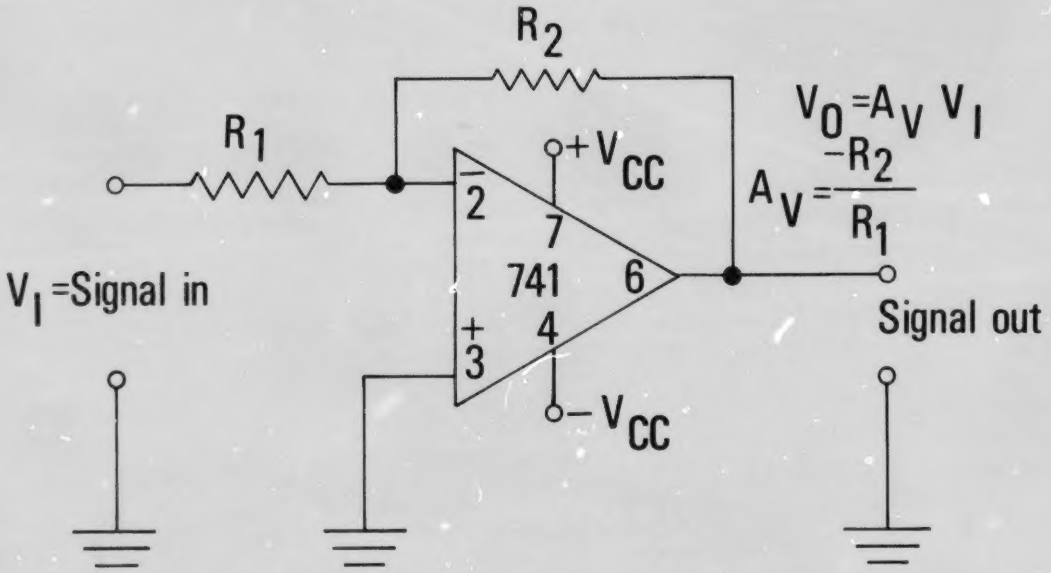


Schematic

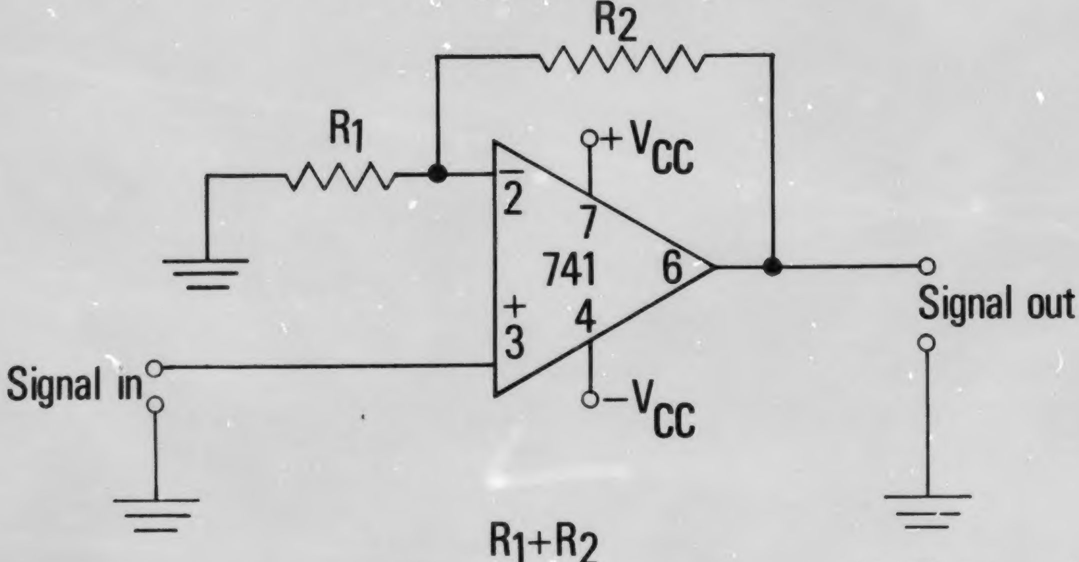
Hybrid Thick Film Circuit


Package Body
Diode
Capacitor
Gold Wire
Lead
Film Resistor
Substrate
Conducting Trace

Inverting and Noninverting Amplifiers


R2
R1
+VCC
−VCC
2
3
7
4
6
741
−
+
V1 =Signal in
Signal out
$V_O = A_V V_I$
$A_V = \frac{-R_2}{R_1}$

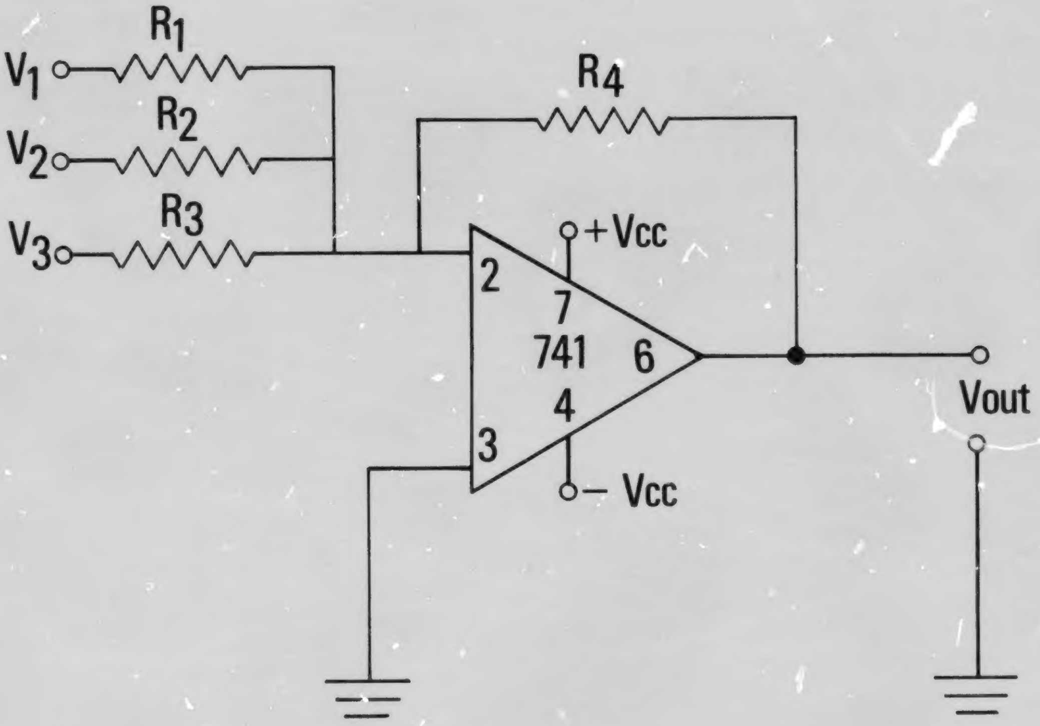
Inverting DC Amplifier


R2
R1
+VCC
−VCC
2
3
7
4
6
741
−
+
Signal in
Signal out

$$A_V = \frac{R_1 + R_2}{R_1} \qquad V_O = V_i A_V$$

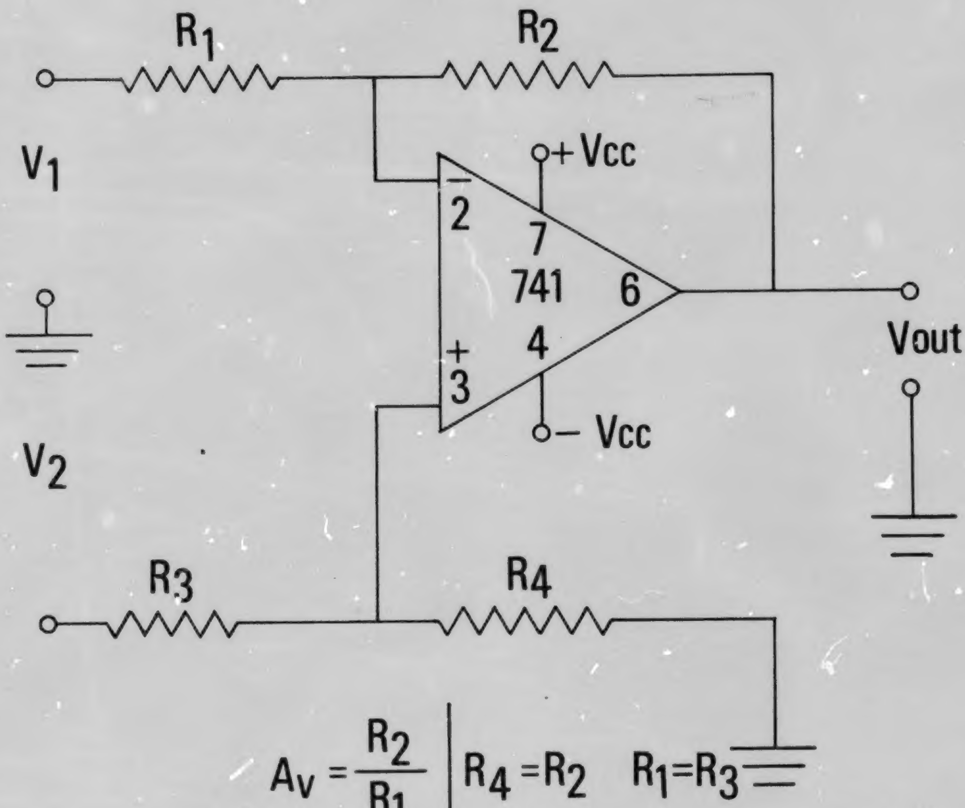
Noninverting DC Amplifier

DC Summing Inverting Amplifier


R1
V1
R2
V2
R3
V3
R4
+Vcc
2
7
741
6
4
3
– Vcc
Vout

$$V_{out} = -R4\left(\frac{V1}{R_1} + \frac{V2}{R_2} + \frac{V3}{R_3}\right)$$

Differential DC Amplifier


R1
R2
V1
+Vcc
−
2
7
741
6
+
4
3
Vout
−Vcc
V2
R3
R4

$A_V = \frac{R_2}{R_1}$ | $R_4 = R_2$ $R_1 = R_3$

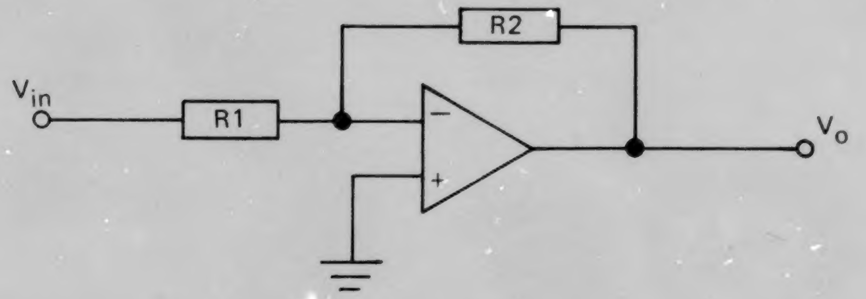
$V_{out} = \frac{R_2}{R_1}(V_2 - V_1)$

OPERATIONAL AMPLIFIERS
UNIT VIII

ASSIGNMENT SHEET #1--CALCULATE THE CLOSED-LOOP GAIN FOR AN INVERTING AND A NONINVERTING AMPLIFIER

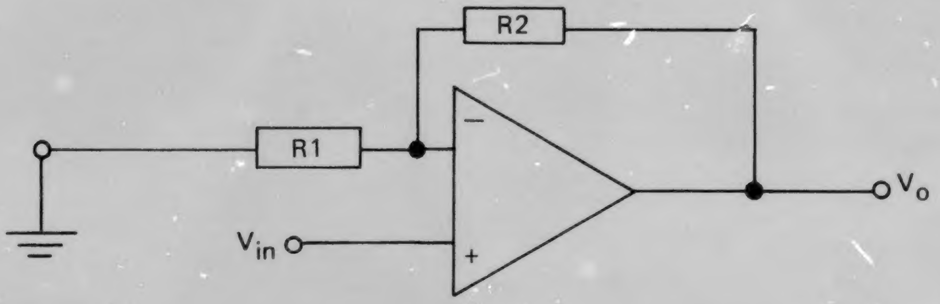
A. Inverting amplifier

1. For the schematic shown below, calculate the closed-loop gain given R_1 = 10K and R_2 = 100K
2. Calculate V_o for part 1 above given V_{in} = + 5 volts.



B. Noninverting amplifier

1. For the schematic shown below, calculate the closed-loop gain given R_1 = 5K and R_2 = 10K
2. Calculate V_{in} for part 1 above given V_o = + 10 volts.



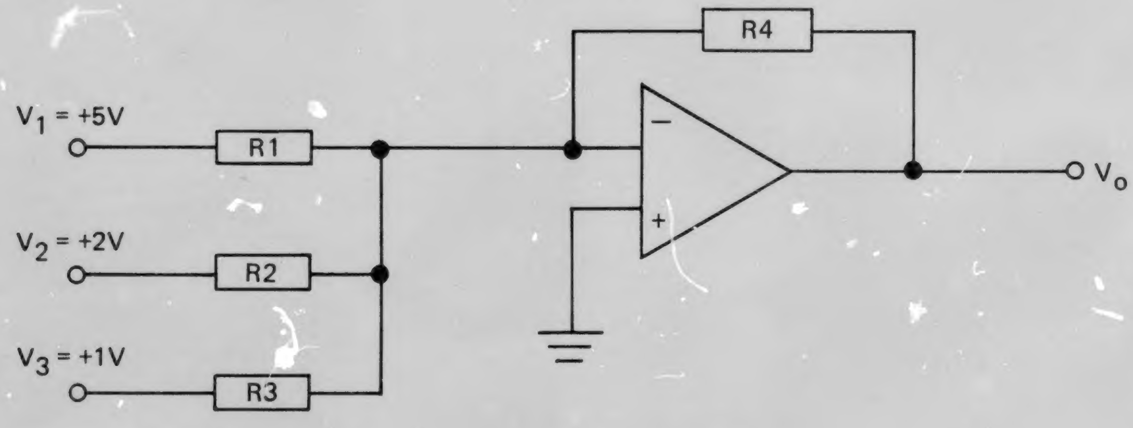
OPERATIONAL AMPLIFIERS
UNIT VIII

ASSIGNMENT SHEET #2--CALCULATE THE OUTPUT VOLTAGE OF A DC SUMMING INVERTING AMPLIFIER

A. For the schematic shown below, R_1 = 10K, R_2 = 5K, R_3 = 10K, R_4 = 10K

Calculate V_o.

B. Repeat part A above if R_4 is 100K


R4
V_1 = +5V
R1
−
+
V_o
V_2 = +2V
R2
V_3 = +1V
R3

OPERATIONAL AMPLIFIERS
UNIT VIII

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

A. Inverting amplifier

1. $A_v = \frac{-R_2}{R_1} = \frac{-100K}{10K} = -10$

2. $A_v = \frac{V_o}{V_{in}}$

$V_o = (A_v)(V_{in}) = (-10)\ (5) = -50$ Volts.

B. Noninverting amplifier

1. $A_v = \frac{R_1 + R_2}{R_1} = 1 + \frac{R_2}{R_1}$

$= 1 + \frac{10K}{5K} = 1 + 2 = 3$

2. $A_v = \frac{V_o}{V_{in}}$

$V_{in} = \frac{V_o}{A_v} = \frac{10}{3} = 3.33$ Volts

Assignment Sheet #2

A. $V_o = -\left[(V_1)\frac{R_4}{R_1} + (V_2)\frac{R_4}{R_2} + (V_3)\frac{R_4}{R_3}\right]$

$V_o = -\left[(5)\frac{10K}{10K} + (2)\frac{10K}{5K} + (1)\frac{10K}{10K}\right]$

$V_o = (5 + 4 + 1) = -10$ Volts.

B. $V_o = -\left[(5)\frac{100K}{10K} + (2)\frac{100K}{5K} + (1)\frac{100K}{10K}\right]$

$= -(50 + 40 + 10)$

$= -100$ Volts

OPERATIONAL AMPLIFIERS
UNIT VIII

JOB SHEET #1--CONSTRUCT AND TEST AN INVERTING AMPLIFIER

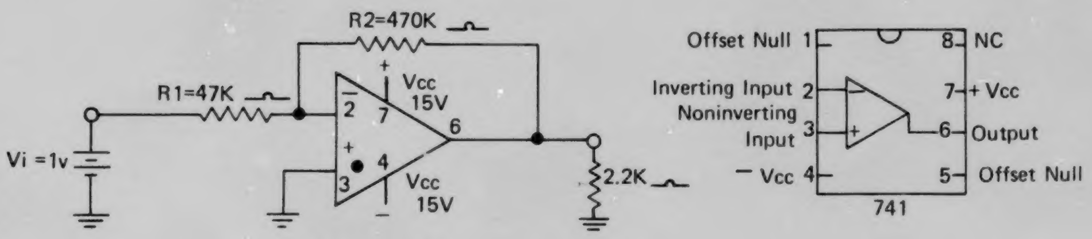
I. Tools and equipment

- A. OP AMP type LM741 or equivalent
- B. 470K resistor 1/4 watt
- C. 47K resistor 1/4 watt
- D. 2.2K resistor 1/4 watt
- E. ± 15 volt DC power supply or dual tracking DC supply
- F. Variable DC power supply
- G. Proto-board or equipment to connect an integrated circuit
- H. Multimeter

II. Procedure

A. Connect the following circuit

(NOTE: Review the data sheet for pin connection for the operational amplifier.)


R2=470K
R1=47K
Vi =1v
Vcc
15V
2
7
6
3
4
+
Vcc
15V
2.2K
Offset Null 1
Inverting Input 2
Noninverting Input 3
− Vcc 4
8 NC
7 + Vcc
6 Output
5 Offset Null
741

B. Calculate the voltage gain

C. Calculate the output voltage across the 2.2K ohm load resistor

D. Apply a 1 volt DC to the input resistor R_1

E. Turn on the power supply (15V) to the operational amplifier

(NOTE: Most operational amplifiers require a power supply that has a + and a minus voltage with reference to a common point [ground].)

JOB SHEET #1

F. Measure and record the output voltage and the input voltage

(NOTE: Be sure to observe the polarity of the output voltage as compared to the input voltage.)

G. Using the measured values calculate the voltage gain; $A_v = V_{out}/V_{in}$

H. Compare the measured gain value (step G) with the calculated gain value (step B)

I. Check your calculations with your instructor

Data Table

A_ν Calculated	Vout Calculated	Vin Measured	Vout Measured	A_ν Measured	% Diff

OPERATIONAL AMPLIFIERS
UNIT VIII

JOB SHEET #2--CONSTRUCT AND TEST A NONINVERTING AMPLIFIER

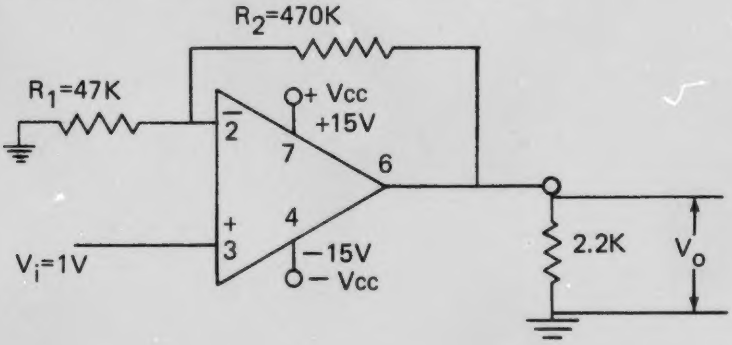
I. Tools and equipment

- A. OP AMP type LM741 or equivalent
- B. 470K resistor 1/4 watt
- C. 47K resistor 1/4 watt
- D. 2.2K resistor 1/4 watt
- E. ± 15 volt DC power supply or dual tracking DC supply
- F. Variable DC power supply
- G. Proto-board or equipment to connect an integrated circuit
- H. Multimeter

II. Procedure

- A. Connect the following circuit for a noninverting DC amplifier.

  (Caution: Do not turn on power at this time.)



- B. Calculate the voltage gain
- C. Calculate the output voltage
- D. Apply 1 volt DC to the noninverting input (pin 3)
- E. Turn on the ± 15 volt power supply
- F. Measure and record the output voltage and the input voltage

  (NOTE: Observe the polarity of the output voltage as compared to the input voltage.)

JOB SHEET #2

G. Using the measured values calculate the voltage gain, $A_v = V_{out} / V_{in}$

H. Compare the measured gain value (step G) with calculated gain value (step B)

I. Check your calculations with your instructor

Data Table

Aν Calculated	Vout Calculated	Vin Measured	Vout Measured	Aν Measured	% Diff

OPERATIONAL AMPLIFIERS
UNIT VIII

JOB SHEET #3--CONSTRUCT AND TEST A DC SUMMING INVERTING AMPLIFIER

I. Tools and equipment

A. OP AMP type LM741 or equivalent

B. 470K resistor 1/4 watt

C. 3-47K resistors 1/4 watt

D. 2.2K resistor 1/4 watt

E. ± 15 V DC power supply or equivalent

F. Variable DC power supply

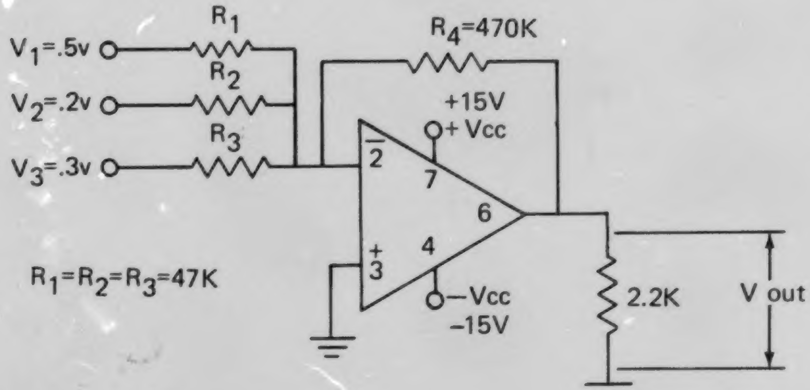
G. Proto-board or equipment to connect an integrated circuit

H. Multimeter

II. Procedure

A. Connect the following circuit for a DC summing inverting amplifier

(CAUTION: Do not turn on the power at this time.)



B. Calculate the output voitage

C. Apply 0.5V to input V_1, 0.2V to input V_2, 0.3 V to input V_3

(NOTE: It may be necessary to build a voltage divider to achieve these input voltages.)

D. Turn on the ± 15 volt power supply

JOB SHEET #3

E. Measure and record the output voltage and the input voltage

(NOTE: Observe the polarity of the output voltage as compared to the input voltage.)

F. Compare the output voltage measured to the output voltage calculated

G. Compute the output voltage if $R_1 = R_2 = R_3 = 470\text{K}$ ohm resistance

H. Compute the output voltage if $R_1 = 4.7\text{K}$ ohm, $R_2 = 3.3\text{K}$ ohm, and $R_3 = 6.8\text{K}$ ohm

I. Check your calculations with your instructor

Data Table

Vout Calculated	Vin Measured	Vout Measured	% Diff	Vout 470K Calculated	Vout 4.7K Calculated

OPERATIONAL AMPLIFIERS
UNIT VIII

JOB SHEET #4--CONSTRUCT AND TEST A DIFFERENTIAL AMPLIFIER

I. Tools and equipment

A. OP AMP type LM741 or equivalent

B. 2-470K resistors

C. 2-47K resistors

D. 1-2.2K resistor

E. ± 15 volt power supply or dual tracking

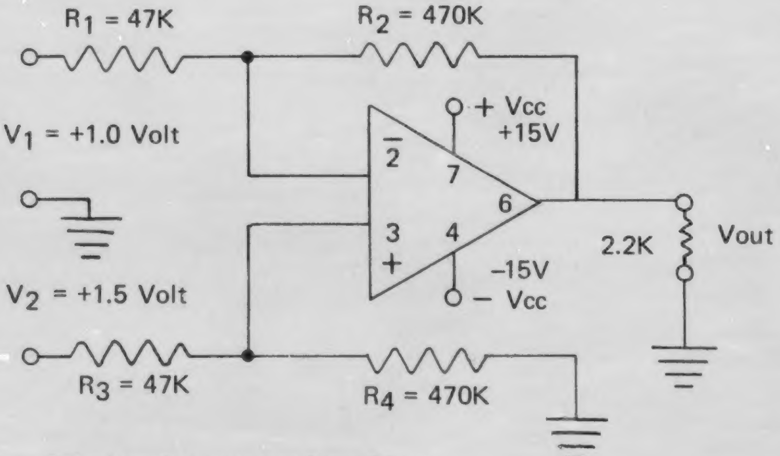
F. 2-DC power supplies (variable)

G. Proto-board or equipment to connect an integrated circuit

II. Procedure

A. Connect the following circuit for a differential DC amplifier

(CAUTION: Do not apply power at this time.)



B. Calculate the output voltage, Vout

C. Apply 1.0 volts at V_1 and 1.5 volts at V_2

(NOTE: You may use two separate power supplies to obtain these inputs.)

D. Turn on the ± 15 volt power supply

E. Measure and record the output voltage and the input voltages

F. Compare the output voltage measured to the output voltage calculated

JOB SHEET #4

G. Adjust V_2 to 1 volt and measure the output voltage

(NOTE: The output voltage should be very small.)

H. Calculate the common mode gain by the following formula:

$$A_C = \frac{Vout}{V_1} \text{ or } \frac{Vout}{V_2}$$

(NOTE: Use values from part G for the above calculation.)

I. Calculate the difference mode gain by the following formula:

$$A_D = \frac{V\ out}{V_2 - V_1}$$

(NOTE: Use values from part E for the above calculation.)

J. Check your calculations with your instructor

Data Table

Vout Measured $V_1 = 1.0V$ $V_2 = 1.5V$	V_1 Measured	V_2 Measured	Vout Calculated	Vout Measured $V_1 = V_2 = 1.0V$	A_C	A_D

OPERATIONAL AMPLIFIERS
UNIT VIII

NAME ______________________________

TEST

1. Match terms on the right with their correct defintions.

______a. A complete electronic circuit this is fabricated on a single chip of silicon

______b. A solid-state integrated circuit amplifier that uses external feedback to control its gain

______c. A classification of integrated circuits used for analog amplification purposes

______d. A classification of integrated circuits used for switching purposes

______e. A complete circuit including active and passive devices and all interconnections fabricated upon a single piece of silicon crystal material

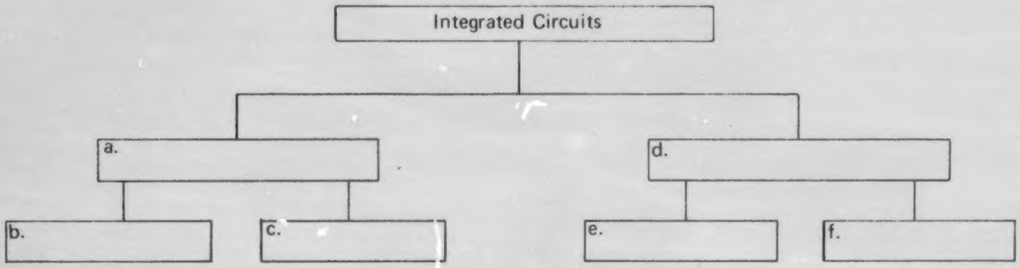
______f. A device which is made by mounting separate components onto a substrate of insulating material such as glass or ceramic

______g. An application of an operational amplifier circuit that uses no external feedback

______h. An application of an operational amplifier circuit that uses external feedback

1. Linear IC
2. Monolithic device
3. Hybrid device
4. Integrated circuit
5. Closed-loop operation
6. Operational amplifier
7. Digital IC
8. Open-loop operation

2. Complete the following diagram to show the categories and subdivisions of integrated circuits.



3. Distinguish between the advantages and disadvantages of integrated circuits by placing an "A" beside advantages and a "D" beside disadvantages.

_____a. Small size

_____b. Limited to low voltage applications

_____c. Low cost

_____d. Limited to low power applications

_____e. High reliability

_____f. Limited component selection

4. Match inverting and noninverting operational amplifiers with their characteristics and Av formulas.

_____a. Output is 180° out of phase with the input

_____b. Input is in phase with the output

_____c. $Av = \frac{-R_2}{R_1}$

_____d. $Av = \frac{R_1 + R_2}{R_1}$

1. Inverting amplifier
2. Noninverting amplifier

5. Match DC summing inverting and differential amplifiers with their characteristics and Vout formulas.

_____a. Output is the sum of the input voltages with a 180° phase shift

_____b. Output is a function of the difference between the two input signals

_____c. $Vout = -R_4\left(\frac{V_1 + V_2 + V_3}{R_1 + R_2 + R_3}\right)$

_____d. $Vout = \frac{R_2}{R_1}\left(V_1 - V_2\right);\ R_1 = R_3;\ R_2 = R_4$

1. DC summing inverting amplifier
2. Differential amplifier

6. Calculate the closed-loop gain for an inverting and a noninverting amplifier.

7. Calculate the output voltage of a DC summing inverting amplifier.

8. Demonstrate the ability to:

   a. Construct and test an inverting amplifier.

   b. Construct and test a noninverting amplifier.

   c. Construct and test a DC summing inverting amplifier.

   d. Construct and test a differential amplfier.

   (NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

OPERATIONAL AMPLIFIERS
UNIT VIII

ANSWERS TO TEST

1. a. 4
   b. 6
   c. 1
   d. 7
   e. 2
   f. 3
   g. 8
   h. 5

2. a. Monolithic
   b. Bipolar
   c. Unipolar
   d. Hybrid circuits
   e. Thick film
   f. Thin film

3. a. A
   b. D
   c. A
   d. D
   e. A
   f. D

4. a. 1
   b. 2
   c. 1
   d. 2

5. a. 1
   b. 2
   c. 1
   d. 2

6. Evaluated to the satisfaction of the instructor

7. Evaluated to the satisfaction of the instructor

8. Performance skills evaluated to the satisfaction of the instructor

LOGIC DEVICES
UNIT IX

UNIT OBJECTIVE

After completion of this unit, the student should be able to identify the schematic symbols for logic devices, complete truth tables for the most common logic devices, and construct and test various IC and discrete logic gate circuits. This knowledge will be evidenced by correctly performing the procedures outlined in the job sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to logic devices with their correct definitions.
2. Identify the schematic symbols for AND gates, OR gates, NAND gates, NOR gates, Exclusive-OR gates, and NOT gates.
3. Complete truth tables for the most common logic devices.
4. Demonstrate the ability to:
    a. Construct and test an IC "AND" gate circuit.
    b. Construct and test an IC "OR" gate circuit.
    c. Construct and test an IC "NAND" gate circuit.
    d. Construct and test an IC "Exclusive-OR" gate circuit.
    e. Construct and test a diode "AND" gate circuit.
    f. Construct and test a diode-transistor "NOR" gate circuit.

LOGIC DEVICES
UNIT IX

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information and job sheets.

III. Make transpariencies.

IV. Discuss unit and specific objectives.

V. Discuss information sheet.

VI. Demonstrate and discuss the procedures outlined in the job sheets.

VII. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit

  A. Objective sheet

  B. Information sheet

  C. Transparency masters

    1. TM 1--AND and OR Gate Symbols and Truth Tables
    2. TM 2--NAND and NOR Gate Symbols and Truth Tables
    3. TM 3--INVERTERS and EXCLUSIVE-OR Gate Symbols and Truth Tables

  D. Job sheets

    1. Job Sheet #1--Construct and Test an IC "AND" Gate Circuit
    2. Job Sheet #2--Construct and Test an IC "OR" Gate Circuit
    3. Job Sheet #3--Construct and Test an IC "NAND" Gate Circuit
    4. Job Sheet #4--Construct and Test an IC "Exclusive-OR" Gate Circuit
    5. Job Sheet #5--Construct and Test a Diode "AND" Gate Circuit
    6. Job Sheet #6--Construct and Test a Diode-Transistor "NOR" Gate Circuit

II. References

A. Tocci, Ronald J. *Fundamentals of Pulse and Digital Circuits.* Columbus, Ohio: Charles E. Merrill Publishing Co., 1977.

B. *TTL Data Book*. Dallas: Texas Instruments, Inc., 1973.

LOGIC DEVICES
UNIT IX

INFORMATION SHEET

I. Terms and definitions

A. Digital circuits--Circuits that produce discontinuous signals at the output terminals

B. Truth table--Summarizes the various combinations of input and corresponding output signals for logic gates

C. High logic level--Usually considered a high voltage for positive logic and symbolized by a "1"

D. Low logic level--Usually considered a low voltage for positive logic and symbolized by a "O"

E. AND gate--Gives a logic output (1) only if all inputs are logic (1)

F. OR Gate--Gives a high level output (1) when any one or more inputs are high (1)

G. Inverter--Changes the output logic level to the opposite logic level of the input; also called a NOT

H. NAND gate--An AND gate followed by an inverter; also called a NOT-AND gate

I. NOR gate--An OR gate followed by an inverter; also called a NOT-OR gate

J. TTL (Transistor-transistor logic)--A means of fabricating an extremely fast operating gate by using a multiemitter transistor

K. MSI (medium-scale integration)--A digital device which contains from 12 to 100 individual basic logic gates

L. LSI (large-scale integration)--A digital device that contains 100 or more individual logic gates

M. Exclusive-OR gate--Gives a high level output when one and only one input is at a high level

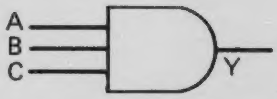
N. DTL (diode transistor logic)--A means of fabricating an operating logic gate using diodes and transistors

INFORMATION SHEET

II. Schematic symbols

A. AND gate (Transparency 1)

1. Symbol--

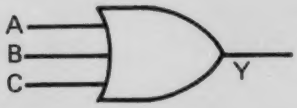


2. Output Y = ABC

(NOTE: ABC refers to A and B and C)

B. OR gate (Transparency 1)

1. Symbol--

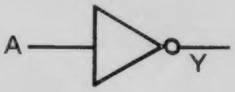


2. Output Y = A + B + C

(NOTE: A + B + C refers to A or B or C)

C. NOT gate (inverter) (Transparency 3)

1. Symbol--

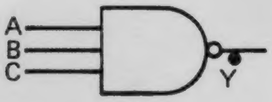


2. Output Y = $\overline{A}$

(NOTE: $\overline{A}$ refers to A inverted)

D. NAND gate (Transparency 2)

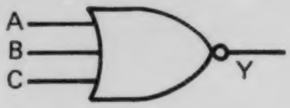
1. Symbol--



2. Output Y = $\overline{ABC}$

E. NOR gate (Transparency 2)

1. Symbol--

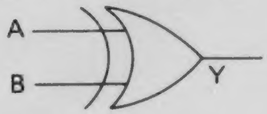


2. Output Y = $\overline{A + B + C}$

INFORMATION SHEET

F. Exclusive-OR gate (Transparency 3)

1. Symbol--



2. Output $Y = \overline{A}B + A\overline{B}$

III. Truth tables

A. AND gate (Transparency 1)

A	B	C	Y
0	0	0	0
0	0	1	0
0	1	0	0
0	1	1	0
1	0	0	0
1	0	1	0
1	1	0	0
1	1	1	1

B. OR gate (Transparency 1)

A	B	C	Y
0	0	0	0
0	0	1	1
0	1	0	1
0	1	1	1
1	0	0	1
1	0	1	1
1	1	0	1
1	1	1	1

C. NOT gate (Transparency 3)

A	Y
0	1
1	0

INFORMATION SHEET

D. NAND gate (Transparency 2)

A	B	C	Y
0	0	0	1
0	0	1	1
0	1	0	1
0	1	1	1
1	0	0	1
1	0	1	1
1	1	0	1
1	1	1	0

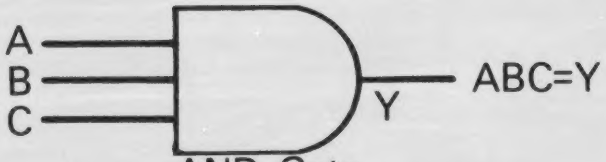
E. NOR gate (Transparency 2)

A	B	C	Y
0	0	0	1
0	0	1	0
0	1	0	0
0	1	1	0
1	0	0	0
1	0	1	0
1	1	0	0
1	1	1	0

F. Exclusive-OR gate (Transparency 3)

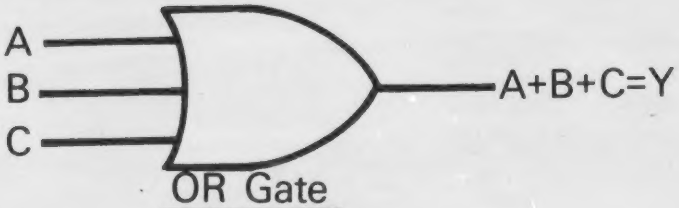
A	B	Y
0	0	0
0	1	1
1	0	1
1	1	0

AND and OR Gate Symbols and Truth Tables



AND Gate

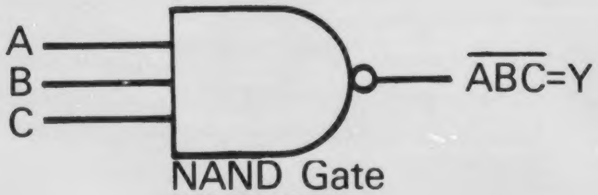
A	B	C	Y
0	0	0	0
0	0	1	0
0	1	0	0
0	1	1	0
1	0	0	0
1	0	1	0
1	1	0	0
1	1	1	1



OR Gate

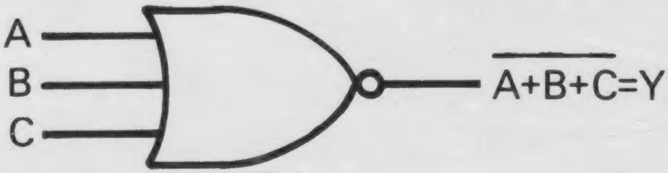
A	B	C	Y
0	0	0	0
0	0	1	1
0	1	0	1
0	1	1	1
1	0	0	1
1	0	1	1
1	1	0	1
1	1	1	1

NAND and NOR Gate Symbols and Truth Tables


A
B
C
$\overline{ABC}=Y$

NAND Gate

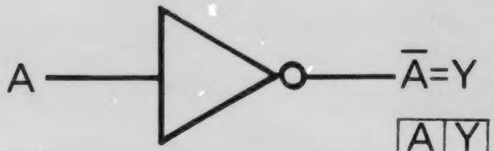
A	B	C	Y
0	0	0	1
0	0	1	1
0	1	0	1
0	1	1	1
1	0	0	1
1	0	1	1
1	1	0	1
1	1	1	0


A
B
C
$\overline{A+B+C}=Y$

NOR Gate

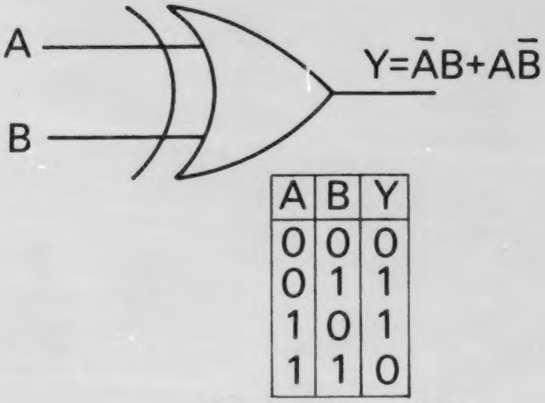
A	B	C	Y
0	0	0	1
0	0	1	0
0	1	0	0
0	1	1	0
1	0	0	0
1	0	1	0
1	1	0	0
1	1	1	0

Inverters and Exclusive – OR Gate Symbols and Truth Tables



NOT Gate

A	Y
0	1
1	0


A
B
$Y=\bar{A}B+A\bar{B}$

A	B	Y
0	0	0
0	1	1
1	0	1
1	1	0

Exclusive - OR

LOGIC DEVICES
UNIT IX

JOB SHEET #1--CONSTRUCT AND TEST AN IC "AND" GATE CIRCUIT

I. Tools and equipment

A. SN7411 triple 3-input positive-AND gates

B. 3 SPDT switches

C. DC power supply (+5 Volt)

D. Multimeter

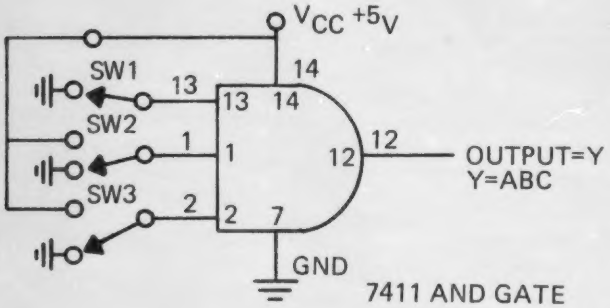
E. Proto-board or equipment system for connecting ICs

F. LED and a 470 ohm resistor (optional)

II. Procedure

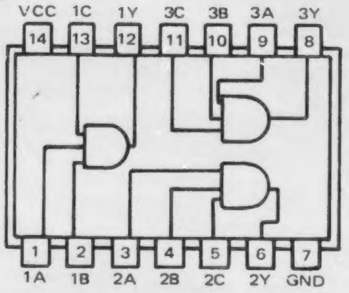
A. Wire the following logic AND gate circuit

(NOTE: This device, 7411, contains three AND gates on one chip, but only one of the gates will be tested.)


V_{CC} +5V
SW1
SW2
SW3
13
1
2
14
12
7
GND
OUTPUT=Y
Y=ABC

7411 AND GATE

Top View


VCC 1C 1Y 3C 3B 3A 3Y
14 13 12 11 10 9 8
1 2 3 4 5 6 7
1A 1B 2A 2B 2C 2Y GND

B. Check with your multimeter to be sure switches are as shown in the above diagram.

(NOTE: The switches may be replaced by simply connecting the inputs to +5 volts or ground.)

C. Connect the multimeter to the output of the gate

(NOTE: A visual output indication may be made by placing an LED and a series resistor [approximately 470 ohms] from the output to ground. The diodes cathode must be connected to ground.)

JOB SHEET #1

D. Complete the following truth table by switching the three input switches into all possible combinations and recording whether the output is a "1" (high voltage) or a "0" (low voltage)

SW-1 Input A	SW-2 Input B	SW-3 Input C	Y Output
0	0	0	
1	1	1	

E. Compare the output results with the truth table given on TM 1

F. Check your results with your instructor

LOGIC DEVICES
UNIT IX

JOB SHEET #2--CONSTRUCT AND TEST AN IC "OR" GATE CIRCUIT

I. Tools and equipment

A. SN7432 Quadruple 2-input positive-OR gates

B. 2-SPDT switches

C. DC power supply

D. Multimeter

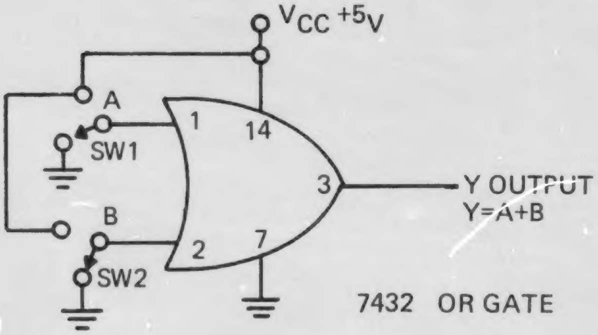
E. Proto-board or equipment system for connecting ICs

F. LED and a 470 ohm resistor (optional)

II. Procedure

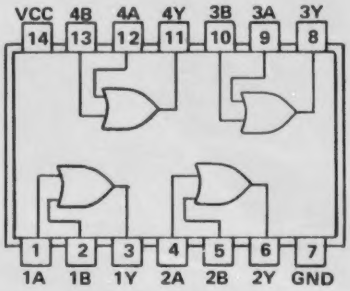
A. Wire the following logic OR gate circuit

(NOTE: This device, 7432, contains four OR gates on one chip but only one of the gates will be tested.)


V_{CC} +5V
A
SW1
1
14
3
Y OUTPUT
Y=A+B
B
2
7
SW2

7432 OR GATE

Top View


VCC
4B
4A
4Y
3B
3A
3Y
14
13
12
11
10
9
8
1
2
3
4
5
6
7
1A
1B
1Y
2A
2B
2Y
GND

B. Check with your multimeter to be sure switches are as shown in the above diagram.

C. Connect the multimeter (DC volts) to the output of the gate

(NOTE: A visual output indication may be made by placing an LED and a series resistor [approximately 470 ohms] from the output to ground. The diodes cathode must be connected to ground.)

JOB SHEET #2

D. Complete the following truth table by switching the two input switches into all possible combinations and record whether the output is a "1" (high voltage) or a "0" (low voltage)

SW-1 Input A	SW-2 Input B	Y Output
0	0	
1	1	

E. Compare the output results with the truth table given on TM 1

F. Check your results with your instructor

LOGIC DEVICES
UNIT IX

JOB SHEET #3--CONSTRUCT AND TEST AN IC "NAND" GATE CIRCUIT

I. Tools and equipment

   A. SN7400 Quadruple 2-input Positive-NAND gates

   B. 2 SPDT switches

   C. DC power supply

   D. Multimeter

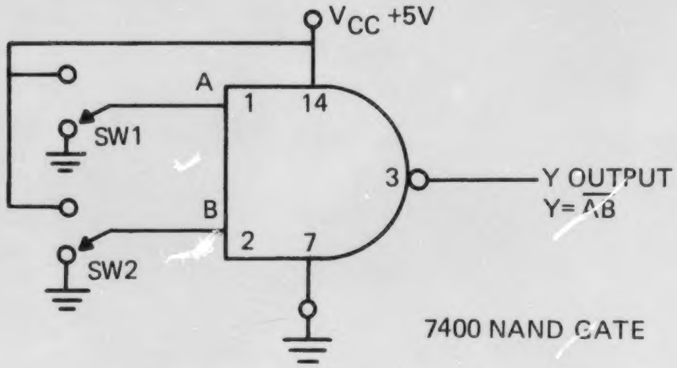
   E. Proto-board or equipment system for connecting ICs

   F. LED and a 470 ohm resistor (optional)

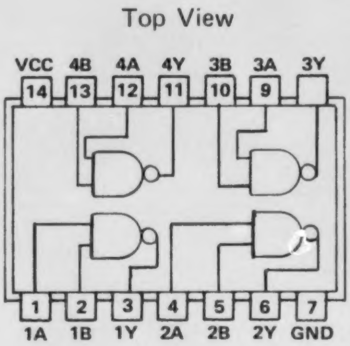
II. Procedure

   A. Wire the following logic NAND gate circuit

   (NOTE: Only one of the four gates on the chip will be tested. This device, SN7400, contains four NAND gates on one chip but only one of the gates will be tested.)


V_{CC} +5V
A
B
1
14
2
7
3
SW1
SW2
Y OUTPUT
$Y=\overline{AB}$

7400 NAND GATE


Top View
VCC
4B
4A
4Y
3B
3A
3Y
14
13
12
11
10
9
1
2
3
4
5
6
7
1A
1B
1Y
2A
2B
2Y
GND

   B. Check with your multimeter to be sure switches are as shown in the above diagram

   C. Connect the multimeter to the output of the gate

   (NOTE: A visual output indication may be made by placing an LED and a series resistor [approximately 470 ohms] from the output to ground. The diodes cathode must be connected to ground.)

JOB SHEET #3

D. Complete the following truth table by switching the two input switches into all possible combinations and recording whether the output is a "1" (high voltage) or a "O" (low voltage)

SW-1 Input A	SW-2 Input B	Y Output
0	0	
1	1	

E. Compare the output results wth the truth table given on TM 2

F. Check your results with your instructor

LOGIC DEVICES
UNIT IX

JOB SHEET #4--CONSTRUCT AND TEST AN IC "EXCLUSIVE-OR" GATE CIRCUIT

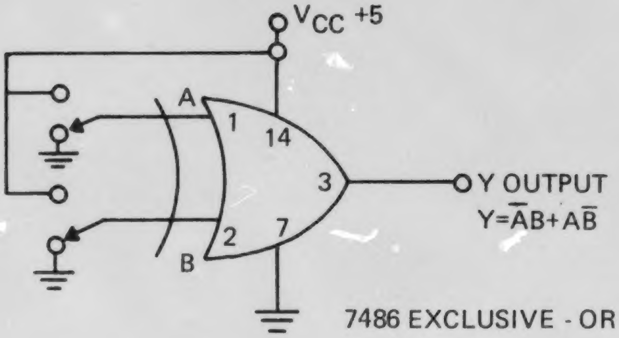
I. Tools and equipment

- A. SN7485 Quadruple 2-input Exclusive-OR gate
- B. 2-SPDT switches
- C. DC power supply
- D. Multimeter
- E. Proto-board or equipment system for connecting ICs
- F. LED and a 470 ohm resistor (optional)

II. Procedure

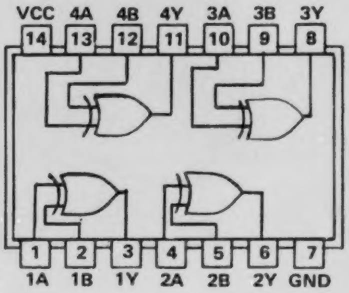
A. Wire the following logic exclusive OR gate circuit

(NOTE: This device, SN7485, contains four Exclusive-OR gates on one chip, but only one of the gates will be tested.)


VCC +5
A
1
14
3
Y OUTPUT
$Y=\overline{A}B+A\overline{B}$
2
7
B

7486 EXCLUSIVE - OR GATE

Top View


VCC
4A
4B
4Y
3A
3B
3Y
14
13
12
11
10
9
8
1
2
3
4
5
6
7
1A
1B
1Y
2A
2B
2Y
GND

B. Check with your multimeter to be sure switches are as shown in the above diagram.

C. Connect the multimeter to the output of the gate

(NOTE: A visual output indication may be made by placing an LED and a series resistor [approximately 470 ohms] from the output to ground. The diodes cathode must be connected to ground.)

JOB SHEET #4

D. Complete the following truth table by switching the two inputs into all possible combinations and recording whether the output is a "1" (high voltage) or a "0" (low voltage)

SW-1 Input A	SW-2 Input B	Y Output
0	0	
1	1	

E. Compare the output results with the truth table given on TM 3

LOGIC DEVICES
UNIT IX

JOB SHEET #5--CONSTRUCT AND TEST A DIODE "AND" GATE CIRCUIT

I. Tools and equipment

A. 3-silicon diodes (any available type)

B. 3-SPDT switches

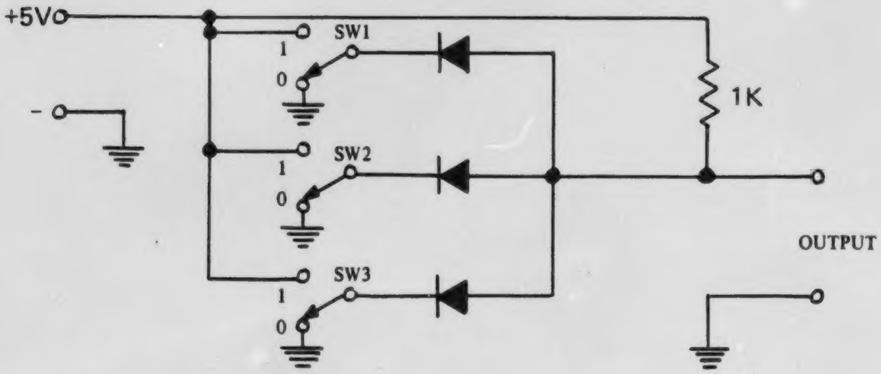
C. 1-1000 ohm Resistor 1/4-watt

D. DC power supply (+5 Volts)

E. Multimeter

II. Procedure

A. Wire the following AND gate circuit



B. Check your multimeter to be sure the switches are shown as the above schematic

(NOTE: Check to see that the polarity of the diodes are as shown.)

C. Connect the multimeter to the output of the gate

(NOTE: A visual output indication may be made by placing an LED and a series resistor [approximately 470 ohms] from the output to ground. The diodes cathode must be connected to ground.)

JOB SHEET #5

D. Complete the following truth table by switching the three switches into all possible combinations and recording whether the output is a "1" (high voltage) or a "0" (low voltage)

SW-1	SW-2	SW-3	Output

E. Check your results with your instructor

LOGIC DEVICES
UNIT IX

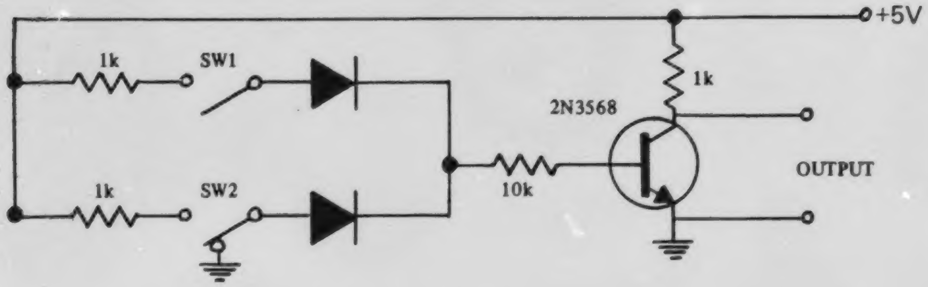
JOB SHEET #6--CONSTRUCT AND TEST A DIODE-TRANSISTOR "NOR" GATE CIRCUIT

I. Tools and equipment

- A. 1-NPN Transistor (2N3568 or equivalent)
- B. 2-silicon diodes (any available type)
- C. 3-1000 ohm resistors, 1/2 W
- D. 1-10K ohm resistor, 1/2 W
- E. 2-SPDT Switches
- F. Multimeter
- G. DC power supply

II. Procedure

- A. Wire the following NOR gate



- B. Check to be sure both switches are in the position shown in the schematic.
- C. Set the multimeter to the correct DC voltage scale and connect it across the transistor output
- D. Note the reading on the multimeter with both inputs "0"
- E. Change SWI to the upper position that connect to ± 5V; this is the "1" position of SW1
- F. Note the multimeter reading

JOB SHEET #6

G. Change SW2 to the "1" position and note the multimeter reading

H. Change SW1 to the "0" position and note the output

I. Change SW2 to the "0" position and note the output

J. Complete the following truth table as indicated by the multimeter output, high or low (assume 3.5V or above is logic one and 0.4 or below is logic zero)

Input		Output
Sw-1	Sw-2	

K. Check your results with your instructor

LOGIC DEVICES
UNIT IX

NAME ______________________________

TEST

1. Match terms on the right with their correct definitions.

_____a. Gives a high level output when any one or more inputs are high

_____b. An AND gate followed by an inverter; also called a NOT-AND gate

_____c. Circuits that produce discontinuous signals at the output terminals

_____d. A digital device that contains 100 or more individual logic gates

_____e. A means of fabricating an extremely fast operating gate by using a multimeter transistor

_____f. An OR gate followed by an inverter; also called a NOT-OR gate

_____g. Summarizes the various combinations of input and corresponding output signals for logic gates

_____h. Usually considered a high voltage for positive logic and symbolized by a "1"

_____i. Gives a logic output only if all inputs are logic

_____j. A digital device which contains from 12 to 100 individual basic logic gates

_____k. Gives a high level output when one and only one input is at a high level

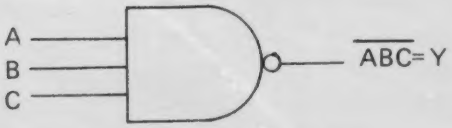
_____l. A means of fabricating an operating logic gate using diodes and transistors

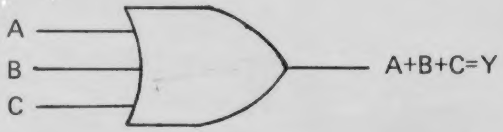
_____m. Changes the output logic level to the opposite logic level of the input; also called a NOT

_____n. Usually considered a low voltage for positive logic and symbolized by a "0"

1. Digital circuits
2. Truth table
3. AND gate
4. OR gate
5. Inverter
6. High logic level
7. Low logic level
8. NAND gate
9. NOR gate
10. TTL
11. MSI
12. LSI
13. Exclusive-OR gate
14. DTL

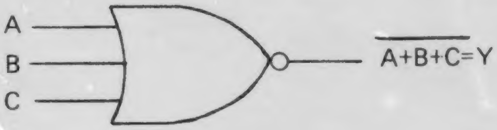
2. Identify the schematic symbols for AND gates, OR gates, NAND gates, NOR gates, Exclusive-OR gates, and NOT gates in the illustrations that follow.

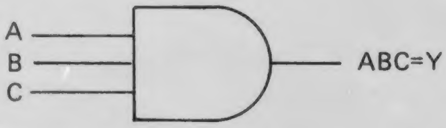

A
B
C
$\overline{ABC}=Y$



a. ______________ Gate

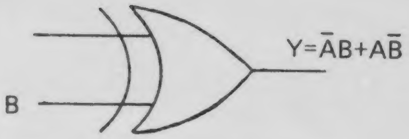
b. ______________ Gate

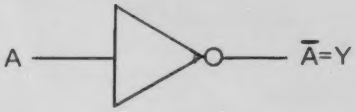

A
B
C
$\overline{A+B+C}=Y$



c. ______________ Gate

d. ______________ Gate


$Y=\overline{A}B+A\overline{B}$
B


A
$\overline{A}=Y$

e. ______________ Gate

f. ______________ Gate

3. Complete truth tables for the most common logic devices listed below.

a. AND gate--

A	B	C	Y
0	0	0	
0	0	1	
0	1	0	
0	1	1	
1	0	0	
1	0	1	
1	1	0	
1	1	1	

b. OR gate--

A	B	C	Y
0	0	0	
0	0	1	
0	1	0	
0	1	1	
1	0	0	
1	0	1	
1	1	0	
1	1	1	

c. NOT gate--

A	Y
0	
1	

d. NAND gate--

A	B	C	Y
0	0	0	
0	0	1	
0	1	0	
0	1	1	
1	0	0	
1	0	1	
1	1	0	
1	1	1	

e. NOR gate--

A	B	C	Y
0	0	0	
0	0	1	
0	1	0	
0	1	1	
1	0	0	
1	0	1	
1	1	0	
1	1	1	

f. Exclusive-OR gate--

A	B	Y
0	0	
0	1	
1	0	
1	1	

4. Demonstrate the ability to:

   a. Construct and test an iC "AND" gate circuit.

   b. Construct and test an IC "OR" gate circuit.

   c. Construct and test an IC "NAND" gate circuit.

   d. Construct and test an IC "Exclusive-OR" gate circuit.

   e. Construct and test an diode "AND" gate circuit.

   f. Construct and test a diode-transistor "NOR" gate circuit.

   (NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

LOGIC DEVICES
UNIT IX

ANSWERS TO TEST

1.

a.	4	f.	9	k.	13
b.	8	g.	2	l.	14
c.	1	h.	6	m.	5
d.	12	i.	3	n.	7
e.	10	j.	11		

2.

a.	NAND Gate	d.	AND Gate
b.	OR Gate	e.	Exclusive-OR Gate
c.	NOR Gate	f.	NOT Gate

3. a. AND gate

A	B	C	Y
0	0	0	0
0	0	1	0
0	1	0	0
0	1	1	0
1	0	0	0
1	0	1	0
1	1	0	0
1	1	1	1

b. OR gate

A	B	C	Y
0	0	0	0
0	0	1	1
0	1	0	1
0	1	1	1
1	0	0	1
1	0	1	1
1	1	0	1
1	1	1	1

c. NOT gate

A	Y
0	1
1	0

d. NAND gate

A	B	C	Y
0	0	0	1
0	0	1	1
0	1	0	1
0	1	1	1
1	0	0	1
1	0	1	1
1	1	0	1
1	1	1	0

e. NOR gate

A	B	C	Y
0	0	0	1
0	0	1	0
0	1	0	0
0	1	1	0
1	0	0	0
1	0	1	0
1	1	0	0
1	1	1	0

f. Exclusive-Or gate

A	B	Y
0	0	0
0	1	1
1	0	1
1	1	0

4. Performance skills evaluated to the satisfaction of the instructor

LOGIC SYSTEMS
UNIT X

UNIT OBJECTIVE

After completion of this unit, the student should be able to write the binary equivalent of decimal numbers, add numbers expressed in binary digits, and complete a truth table for a half-adder. The student should also be able to identify multivibrators, and construct and test a four-bit shift register. This knowledge will be evidenced by correctly performing the procedures outlined in the assignment and job sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to logic systems with their correct definitions.
2. Convert a sequence of binary numbers to decimal numbers.
3. Add binary numbers.
4. Complete a truth table for a half-adder.
5. Identify multivibrators given their input and output signal waveforms.
6. Convert decimal numbers to their equivalent BCD.
7. Add numbers expressed in binary digits.
8. Demonstrate the ability to construct and test a four-bit shift register.

LOGIC SYSTEMS
UNIT X

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information, assignment, and job sheets.

III. Make transparencies.

IV. Discuss unit and specific objectives.

V. Discuss information and assignment sheets.

VI. Demonstrate and discuss the procedures outlined in the job sheet.

VII. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

- A. Objective sheet
- B. Information sheet
- C. Transparency masters
    1. TM 1--Binary to Decimal Conversions
    2. TM 2--Binary Addition
    3. TM 3--Half-Adder Logic
    4. TM 4--Multivibrators
    5. TM 5--Binary Coded Decimals
- D. Assignment Sheet #1--Add Numbers Expressed in Binary Digits
- E. Answers to assignment sheet
- F. Job Sheet #1--Construct and Test a Four-Bit Shift Register
- G. Test
- H. Answers to test

II. References:

A. Tocci, Ronald J. *Fundamentals of Pulse and Digital Circuits*. Columbus, Ohio: Charles E. Merrill Publishing Co., 1977.

B. *TTL Data Book*. Dallas: Texas Instruments, Inc., 1973.

LOGIC SYSTEMS
UNIT X

INFORMATION SHEET

I. Terms and definitions

   A. Binary number system--Lowest useful number system which has digits 0 and 1 only

   B. Bit--A single binary digit, 0 or 1

   C. Byte--8 bits

   D. Half-adder--A combination of AND gates, OR gates, and INVERTERS used to perform binary addition of two single digit numbers

   E. Full-adder--A combination of two half-adders which requires the three inputs of A, B, and the previous carry

   F. Flip-flop (bistable multivibrator)--A circuit that is stable in two states (0 or 1) and is used as a memory element in digital circuits

   G. One-shot (monostable multivibrator)--A circuit that is stable in only one state and is used in timing and pulse-shaping circuits

   H. Free-running (astable multivibrator)--Provides a fixed-frequency square wave often referred to as a clock

   I. Binary coded decimal (BCD)--A digital code where a four bit binary character is used to represent each one digit decimal character

   J. Discrete devices--Individual components such as transistors and diodes (a single device)

II. Binary to Decimal Conversions (Transparency 1)

   A. Number places, i.e., $\overset{2^3}{1}\ \overset{2^2}{0}\ \overset{2^1}{1}\ \overset{2^0}{1}$

   B. Number conversions--Binary to decimal

III. Binary addition (Transparency 2)

   A. Add unit digits

INFORMATION SHEET

B. Carry from right to left

Example: To find the sum of $\begin{array}{r} 1\ 0\ 1 \\ +\ 0\ 0\ 1 \\ \hline \end{array}$, proceed as follows:

1. Add unit digits starting from right column

$$\begin{array}{r} 1 \\ +\ 1 \\ \hline 10 \end{array}$$

(NOTE: This number has a carry which must be added to the next column of digits to the left.)

2. Add second column from right

$$\begin{array}{rl} 1 & \text{(carry from first column)} \\ 0 & \\ +\ 0 & \\ \hline 1 & \end{array}$$

(NOTE: No carry on this addition.)

3. Add third column from right

$$\begin{array}{rl} 0 & \text{(No carry from second column)} \\ 1 & \\ +\ 0 & \\ \hline 1 & \end{array}$$

4. Total all columns and the sum of $\begin{array}{r} 1\ 0\ 1 \\ +\ 0\ 0\ 1 \\ \hline 1\ 1\ 0 \end{array}$

IV. Truth table for a half-adder (Transparency 3)

A. Has a sum and a carry output

B. Used for adding two single digit numbers

(NOTE: A carry occurs only when the inputs are both equal to 1.)

V. Multivibrators and their input and output signal waveforms (Transparency 4)

A. Flip-flop--Bistable multivibrator

B. One-shot--Monostable multivibrator

C. Free-running--Astable multivibrator

INFORMATION SHEET

VI. Binary Coded Decimal (BCD) numbers (Transparency 5)

  A. BCD system--Coding structure

  B. Conversion from decimal to BCD

Binary to Decimal Conversions

A. $1011_2 = \underset{(8)}{\overset{2^3}{1}}\ \underset{(4)}{\overset{2^2}{0}}\ \underset{(2)}{\overset{2^1}{1}}\ \underset{(1)}{\overset{2^0}{1}} = (1x8)+(0x4)+(1x2)+(1x1) + 8+0+2+1 = 11_{(10)}$

B. $111_2 = \underset{(4)}{\overset{2^2}{1}}\ \underset{(2)}{\overset{2^1}{1}}\ \underset{(1)}{\overset{2^0}{1}} = (1x4)+(1x2)+(1x1) = 4+2+1 = 7_{(10)}$

C. $11011_{27} = \overset{2^4}{1}\ \overset{2^3}{1}\ \overset{2^2}{0}\ \overset{2^1}{1}\ \overset{2^0}{1} = (1x16)+(1x8)+(0x4)+(1x2)+(1x1) = 16+8+0+2+1 = 27_{10}$

Binary Addition

Rules For Binary Addition:

$0+0=0$

$0+1=1$

$1+0=1$

$1+1=10$

Binary **Digital**

A.

$$\begin{array}{r} 01 \\ +\ 10 \\ \hline 11 \end{array} \qquad \begin{array}{r} (1) \\ +\ (2) \\ \hline 3 \end{array}$$

B.

$$\begin{array}{r} \overset{\text{carry}}{1}\ \overset{\text{carry}}{1} \\ 11 \\ 01 \\ \hline 100 \end{array} \qquad \begin{array}{r} 3 \\ +\ 1 \\ \hline 4_{10} \end{array}$$

(NOTE: $1+1 = 0+$a carry 1)

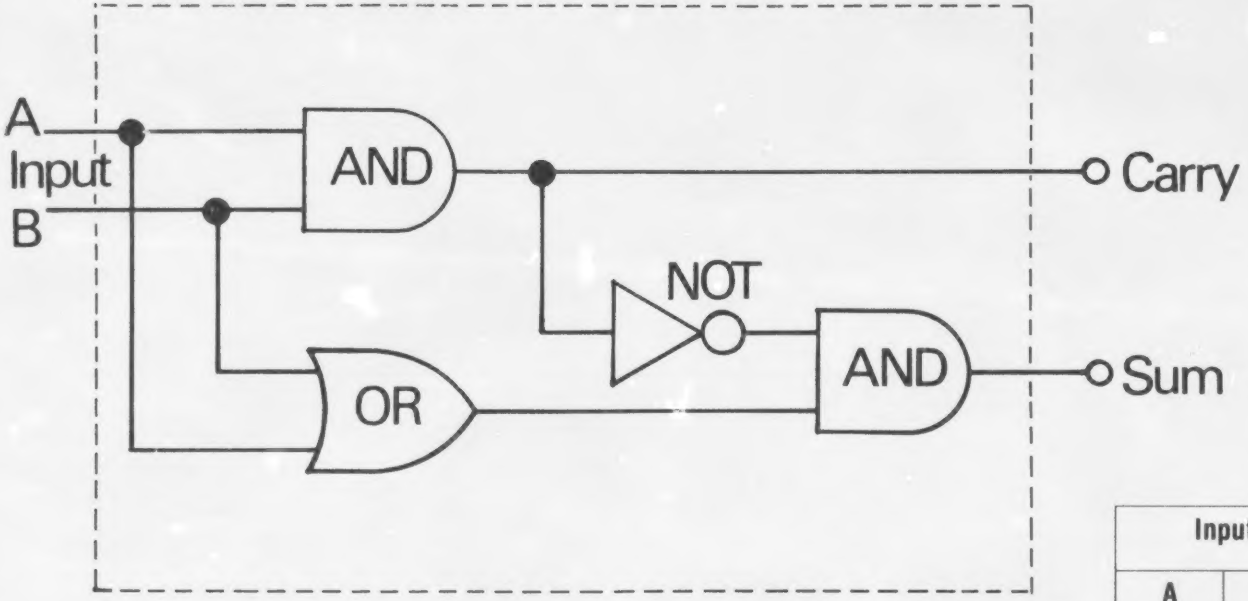
C.

$$\begin{array}{r} \overset{\text{carry}}{\swarrow}\,\overset{\text{carry}}{\swarrow}\,\overset{\text{carry}}{\swarrow} \\ 1101 \\ +\ 111 \\ \hline 10100_{(2)} \end{array} \qquad \begin{array}{r} 13 \\ +\ 7 \\ \hline 20_{(10)} \end{array}$$

D.

$$\begin{array}{r} 1\,1\,1\ \ \ \\ 10110 \\ 01010 \\ \hline 100000_{(2)} \end{array} \ = \ \begin{array}{r} 22 \\ 10 \\ \hline 32_{10} \end{array}$$

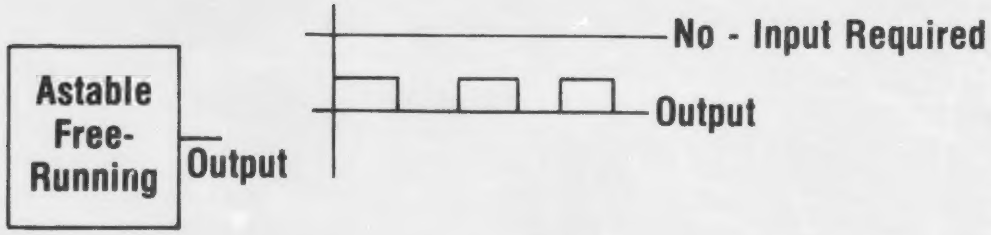
Half-Adder Logic

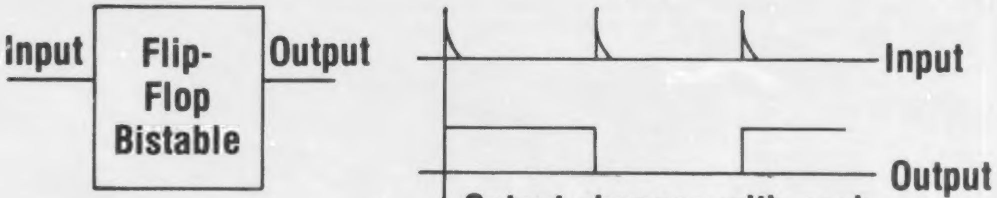

A
Input
B
AND
Carry
NOT
AND
OR
Sum

Truth Table

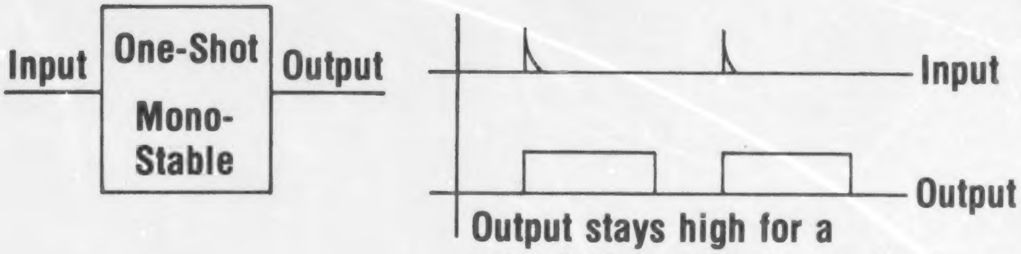
Input		Output	
A	B	C	S
0	0	0	0
0	1	0	1
1	0	0	1
1	1	1	0

Multivibrators


Astable
Free-
Running
Output
No - Input Required
Output


Input
Flip-
Flop
Bistable
Output
Input
Output

Output changes with each input pulse


Input
One-Shot
Mono-
Stable
Output
Input
Output

Output stays high for a period of time then goes back to its normally low state

Multivibrators may be made from either discrete devices or integrated circuits

Binary Coded Decimals

BCD States

Binary		Decimal
0000	Allowable States	0
0001		1
0010		2
0011		3
0100		4
0101		5
0110		6
0111		7
1000		8
1001		9

Binary		Decimal
1010	Disallowable States	10
1011		11
1100		12
1101		13
1110		14
1111		15

Four bits represent each decimal digit

	7	4	decimal
	0111	0100	BCD code
	3	6	decimal
	0011	0110	BCD code
	9	9	decimal
	1001	1001	BCD code
3	8	4	decimal
0011	1000	0100	BCD code

LOGIC SYSTEMS
UNIT X

ASSIGNMENT SHEET #1--ADD NUMBERS EXPRESSED IN BINARY DIGITS

A. The binary equivalent for the decimal number 20 is 10100. The binary equivalent for the decimal number 17 is 10001. Add the two binary equivalent numbers and check by converting your answer in binary back to a decimal number.

B. Add the following binary numbers:

```
  100011
+110101
+101011
```

Sum:

What is the decimal equivalent of your answer?________________________

C. Convert the decimal number 375 to equivalent BDC code.

LOGIC SYSTEMS
UNIT X

ANSWERS TO ASSIGNMENT SHEET

A.

$$\begin{array}{rr} 10100 & 20 \\ +10001 & 17 \\ \hline 100101 & 37 \end{array}$$

B.

$$\begin{array}{rr} 100011 & 35 \\ 110101 & 53 \\ 101011 & 43 \\ \hline 10000011 & 131 \end{array}$$

C. 0011 0111 0101

LOGIC SYSTEMS
UNIT X

JOB SHEET #1--CONSTRUCT AND TEST A FOUR-BIT SHIFT REGISTER

I. Tools and equipment

  A. 2-SN7473 Dual J-K Flip-flops

  B. DC power supply (+5 volts)

  C. 4-LEDs

  D. 4-470 ohm resistors

  E. Proto-board or equivalent system for connecting ICs

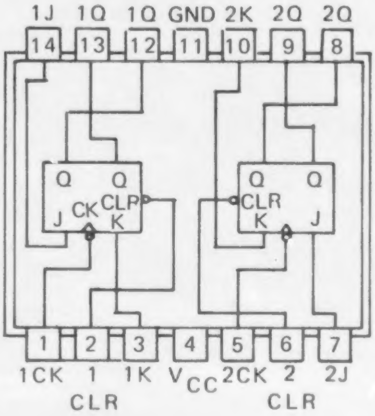
  F. Function generator or means of producing a square wave pulse with a single step capability

  G. 1-SN7404 HEX inverter

  (NOTE: This experiment will use four flip-flops (J-K Flip-flops) to transfer the contents of the first flip-flop (register) into a second flip-flop (register) and so on, one bit at a time. This type of circuit is called a shift register.)

'73,'H73,'L73
FUNCTION TABLE

INPUTS				OUTPUTS	
CLEAR	CLOCK	J	K	Q	Q
L	X	X	X	L	H
H	⎍	L	L	Q_0	Q_0
H	⎍	H	L	H	L
H	⎍	L	H	L	H
H	⎍	H	H	TOGGLE	

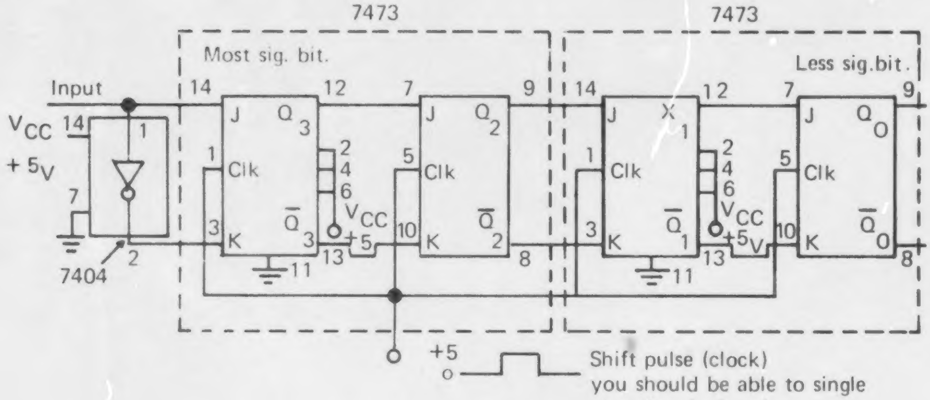

1J
1Q
1Q
GND
2K
2Q
2Q
14
13
12
11
10
9
8
Q
Q
J
CK
CLR
K
Q
Q
CLR
K
J
1
2
3
4
5
6
7
1CK
1 CLR
1K
V_{CC}
2CK
2 CLR
2J

JOB SHEET #1

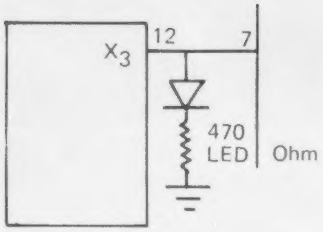
II. Procedure

A. Connect the following circuit

(NOTE: If data books are available, study the logic diagrams for the 7473 and the 7404 logic chips.)


7473
7473
Most sig. bit.
Less sig.bit.
Input
Vcc
+ 5V
14
1
7
2
7404
14
12
7
9
J
Q3
Clk
K
Q̄3
2
4
6
Vcc
+5
13
11
1
3
5
10
J
Q2
Clk
K
Q̄2
8
14
12
7
9
J
X1
Clk
K
Q̄1
2
4
6
Vcc
+5V
13
11
1
3
5
10
J
Q0
Clk
K
Q̄0
8
+5
0

Shift pulse (clock) you should be able to single step the clock pulse


X3
12
7
470
LED
Ohm

Output indicators place an LED and resistor on each of the flip - -flops X output (X_3, X_2, X_1, X_0)

(NOTE: The outputs of all flip-flops should be "0" before you start. If not, momentarily ground the clear pin (2 or 6) for the output which is high. You may want to try shifting additional numbers through the four bit binary shift register.

The binary number 1 0 1 1 will be shifted through the shift register one bit at a time starting with the least significant bit (the far right bit) and moving from right to left.)

B. Place a logic level "1" on the input terminal by connecting the input terminal to + Vcc (5v)

JOB SHEET #1

C. Push the shift pulse switch or clock pulse switch one time

D. Record the outputs of each flip-flop; X_3, X_2, X_1, X_0

(NOTE: The LED should light for "1" and be off for a "0.")

E. The next bit to be entered is also a "1" (1 0 $\underline{1}$ 1) so push the shift pulse switch one time

F. Record the outputs of each flip-flop

G. Place a "0" on the input terminal by changing the input from + 5 volts to ground

H. Push the shift pulse switch

I. Record the outputs of each flip-flop

J. Place a "1" on the input terminal by changing the input from ground to +5v (Vcc)

K. Push the shift pulse switch

L. Record the outputs of each flip-flop

M. Check your results with your instructor

LOGIC SYSTEMS
UNIT X

NAME ______________________________

TEST

1. Match terms on the right to their correct definitions.

_____a. 8 bits

_____b. A combination of two half-adders which requires the three inputs of A, B, and the previous carry

_____c. A circuit that is stable in only one state and is used in timing and pulse-shaping circuits

_____d. A digital code where a four bit binary character is used to represent each one digit decimal character

_____e. Lowest useful number system which has digits 0 and 1 only

_____f. A combination of AND gates, OR gates, and INVERTERS used to perform binary addition of two single digit numbers

_____g. A single binary digit, 0 or 1

_____h. Provides a fixed-frequency square wave often referred to as a clock

_____i. A circuit that is stable in two states and is used as a memory element in digital circuits

_____j. Individual components such as transistors and diodes

1. Binary number system
2. Bit
3. Byte
4. Half-adder
5. Full-adder
6. Flip-flop
7. One-shot
8. Free-running
9. Binary coded decimal
10. Discrete devices

2. Convert the following sequence of binary numbers to decimal numbers.

a. 01 _____

b. 10 _____

c. 11 _____

d. 100 _____

e. 101 _____

f. 110 _____

g. 111 _____

h. 1000 _____

i. 1001 _____

j. 1010 _____

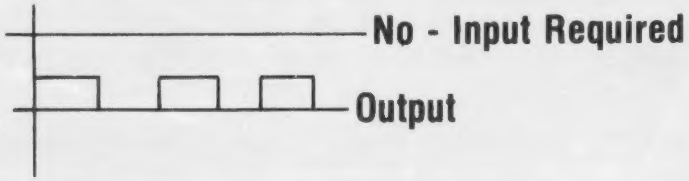
3. Add the following binary numbers.

1 0 0 0 1 1
1 1 0 1 0 1
1 0 1 0 1 1

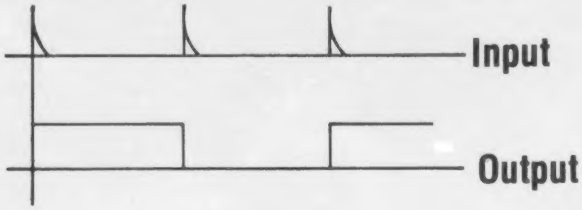
4. Complete the following truth table for a half-adder.

Input		Output	
A	B	C	S
0	0	0	0
	1	0	1
1		0	
1	1		0

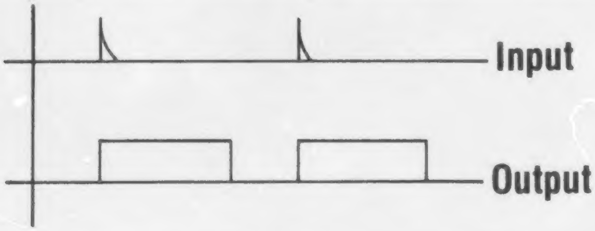
5. Identify multivibrators from their input and output signal waveforms.


No - Input Required
Output

a.


Input
Output

b.


Input
Output

c.

6. Convert the following decimal numbers to their equivalent BCD codes.

   a. 3972 ____________________

   b. 2874 ____________________

   c. 8197 ____________________

7. Add numbers expressed in binary digits.

8. Demonstrate the ability to construct and test a four-bit shift register.

   (NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

LOGIC SYSTEMS
UNIT X

ANSWERS TO TEST

1.	a. 3		f. 4	
	b. 5		g. 2	
	c. 7		h. 8	
	d. 9		i. 6	
	e. 1		j. 10	
2.	a. 1		f. 6	
	b. 2		g. 7	
	c. 3		h. 8	
	d. 4		i. 9	
	e. 5		j. 10	

3.

$$\begin{array}{r@{\qquad\qquad}r} 100011 & 35 \\ 110101 & 53 \\ \underline{101011} & \underline{43} \\ 10000011 & 131 \end{array}$$

4.

Input		Output	
A	B	C	S
0	0	0	0
0	1	0	1
1	0	0	1
1	1	1	0

5. a. Free-running or astable

   b. Flip-flop or bistable

   c. One-shot or monostable

6.

a.	0011	1001	0111	0010
b.	0010	1000	0111	0100
c.	1000	0001	1001	0111

7. Evaluated to the satisfaction of the instructor

8. Performance skills evaluated to the satisfaction of the instructor

SPECIAL SEMICONDUCTOR DEVICES
UNIT XI

UNIT OBJECTIVE

After completion of this unit, the student should be able to identify the schematic symbols and output characteristic curves for various special semiconductor devices, state the applications for various special semiconductor devices, and construct and test various special semiconductor device circuits. This knowledge will be evidenced by correctly performing the procedures outlined in the job sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to special semiconductor devices with their correct definitions.
2. Identify the schematic symbol for an SCR.
3. Sketch the output characteristic curves of an SCR.
4. Select true statements concerning other characteristics of an SCR.
5. Identify the schematic symbol for a Triac.
6. Sketch the output characteristic curves of a Triac.
7. Identify the schematic symbol for a Diac.
8. Select true statements concerning Diac applications.
9. Distinguish between the schematic symbols for two types of thermistors.
10. Select true statements concerning thermistor applications.
11. Identify the schematic symbol for a UJT.
12. Sketch the output characteristic curves of a UJT.
13. Select true statements concerning UJT applications.
14. Identify the schematic symbol for a PUT.
15. Distinguish between the advantages of a PUT over a UJT.
16. Identify the schematic symbols for a JFET.
17. Sketch the output characteristic curves of a JFET.
18. Distinguish between the schematic symbols for the two types of MOSFETs.

19. Select true statements concerning the characteristics of IGFETs or MOSFETs.

20. Demonstrate the ability to:

    a. Construct and test a silicon controlled rectifier circuit.

    b. Construct and test a unijunction transistor relaxation oscillator.

    c. Construct and test a field effect transistor amplifier.

    d. Construct and test a thermistor controlled circuit.

SPECIAL SEMICONDUCTOR DEVICES
UNIT XI

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information and job sheets.

III. Make transparencies.

IV. Discuss unit and specific objectives.

V. Discuss information sheet.

VI. Demonstrate and discuss the procedures outlined in the job sheets.

VII. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

   A. Objective sheet

   B. Information sheet

   C. Transparency masters

      1. TM 1--Silicon Controlled Rectifier
      2. TM 2--Triac
      3. TM 3--Unijunction Transistor
      4. TM 4--Junction Field Effect Transistor
      5. TM 5--Insulated Gate Field Effect Transistors

   D. Job sheets

      1. Job Sheet #1--Construct and Test a Silicon Controlled Rectifier Circuit
      2. Job Sheet #2--Construct and Test a Unijunction Transistor Relaxation Oscillator
      3. Job Sheet #3--Construct and Test a Field Effect Transistor Amplifier
      4. Job Sheet #4--Construct and Test a Thermistor Control Circuit

   E. Test

   F. Answers to test

SPECIAL SEMICONDUCTOR DEVICES
UNIT XI

INFORMATION SHEET

I. Terms and definitions

   A. Thyristors--A family of multilayered semiconductor devices which are used primarily for switching current

   B. SCR (Silicon Controlled Rectifier)--A three-terminal device similar to an ordinary rectifier except its rectifying characteristics can be controlled; a member of the thyristor family

   C. Triac--A three-terminal device which is a member of the thysistor family and is generally applied as an AC switching device

   D. Diac--A bidirectional trigger diode

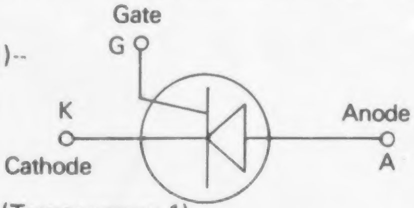
   E. Thermistor--A temperature-sensitive resistor

   F. UJT (Unijunction Transistor)--A specialized type of junction transistor which is normally used as a switching device

   G. FET (Field Effect Transistor)--A specialized type of transistor which is voltage controlled and has very high input impedance

   H. PUT (Programmable Unijunction Transistor)--A specialized semiconductor device used for switching purposes; it has a trigger voltage that is programmable

II. SCR schematic symbol (Transparency 1)--



III. Output characteristic curves of an SCR (Transparency 1)

   A. Gate current

   B. Forward breakover voltage

   C. Holding current

   D. Normal rectifier characteristic

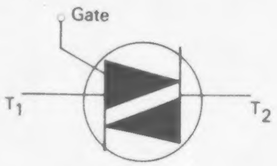
IV. Other characteristics of an SCR

   A. Small gate current required to turn on device when P-N junction is forward biased

   B. Remains on until anode to cathode current is reduced below minimum holding current , I_H

INFORMATION SHEET

V. Triac schematic symbol (Transparency 2)--



VI. Output characteristic curves of a Triac (Transparency 2)

  A. Forward condition

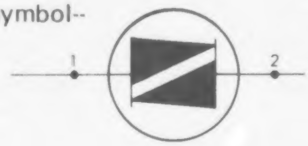
  B. Reverse condition

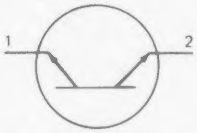
  C. Forward breakover

  D. Reverse breakover

  E. AC switch characteristic

VII. Diac schematic symbol--





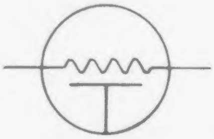
VIII. Diac applications

  A. Used to trigger Triacs

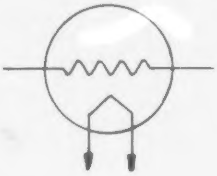
  B. Provides protection against overvoltages

IX. Thermistor schematic symbols

  A. Directly heated--



  B. Indirectly heated--



X. Thermistor applications

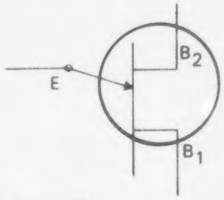
  A. Used when a negative temperature coefficient is required

  B. Detects changes in the temperature of the surroundings

  C. Detects changes in current flow by indirect heating of the device

INFORMATION SHEET

XI. UJT schematic symbol (Transparency 3)--



XII. Output characteristic curves of a UJT (Transparency 3)

A. Resistance from base-1 to emitter is high at low-emitter voltages

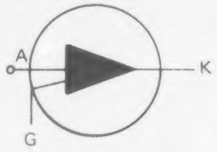
B. When emitter voltage reaches the forward-bias level, the base-1 resistance drops quite suddenly between base-1 and emitter

XIII. UJT applications

A. Wave-shaping generators

B. Pulse-forming circuits

XIV. PUT schematic symbol--



XV. Advantages of a PUT over a UJT (or transistor switch)

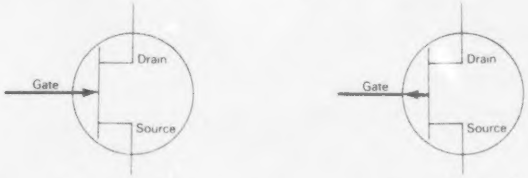
A. Higher breakdown voltage

B. Low voltage operation capability

C. Programmable trigger voltage

D. Low cost and small size

XVI. JFET schematic symbols (Transparency 4)--



N - Channel

P - Channel

XVII. Output characteristic curves of a JFET

A. Reverse-bias junction (gate to source) controls output

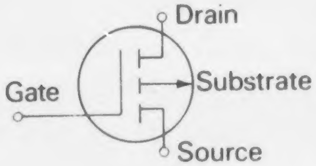
B. Normally "on" device conducts when voltage is applied between the drain and the source

C. High input impedance because of the reverse-biased junction

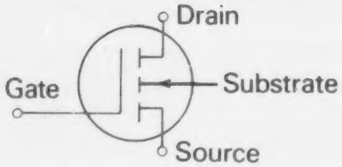
INFORMATION SHEET

XVIII. MOSFET schematic symbols

A. Enhancement mode--

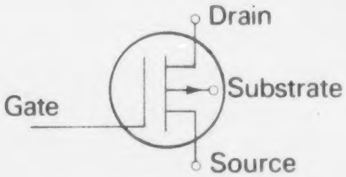

Drain
Gate
Substrate
Source

P - Channel

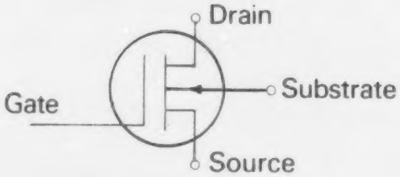

Drain
Gate
Substrate
Source

N - Channel

B. Depletion mode--


Drain
Gate
Substrate
Source

P - Channel


Drain
Gate
Substrate
Source

N - Channel

XIX. Characteristics of IGFETs or MOSFETs

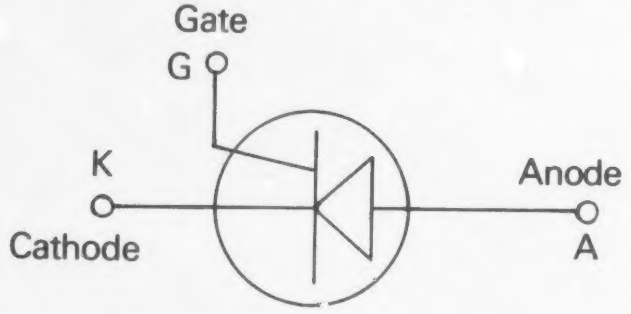
A. Gate insulated from source and drain

B. High input impedance because of the insulation layer

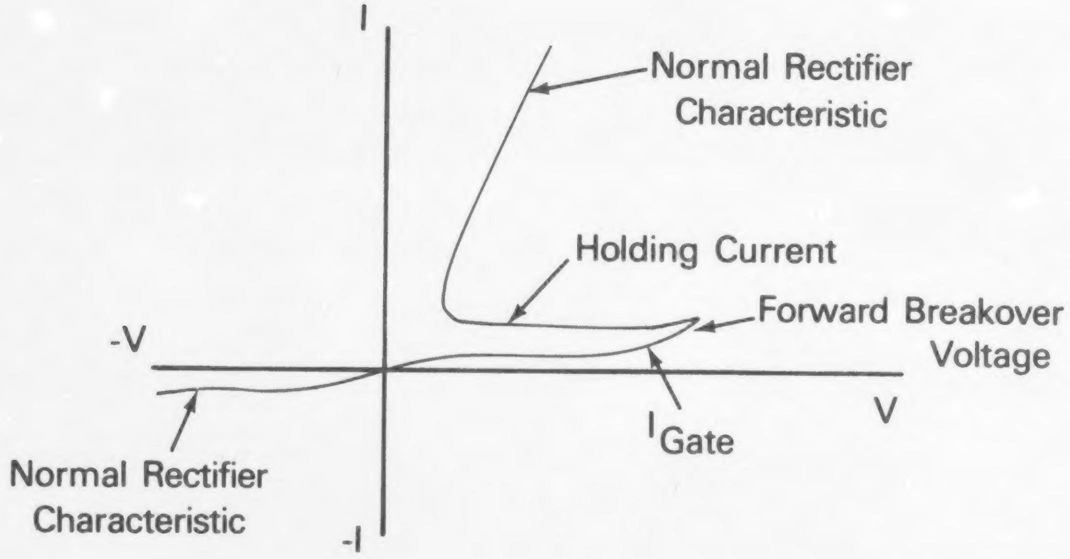
C. Enhancement type is normally "off" and has no deposited channel region

D. Depletion type is normally "on" and has a deposited channel region

Silicon Controlled Rectifier

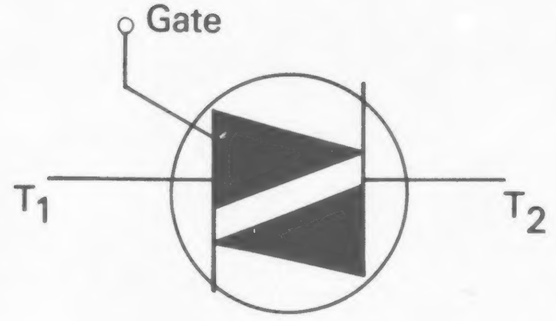

Gate
G
K
Cathode
Anode
A

Schematic Symbol

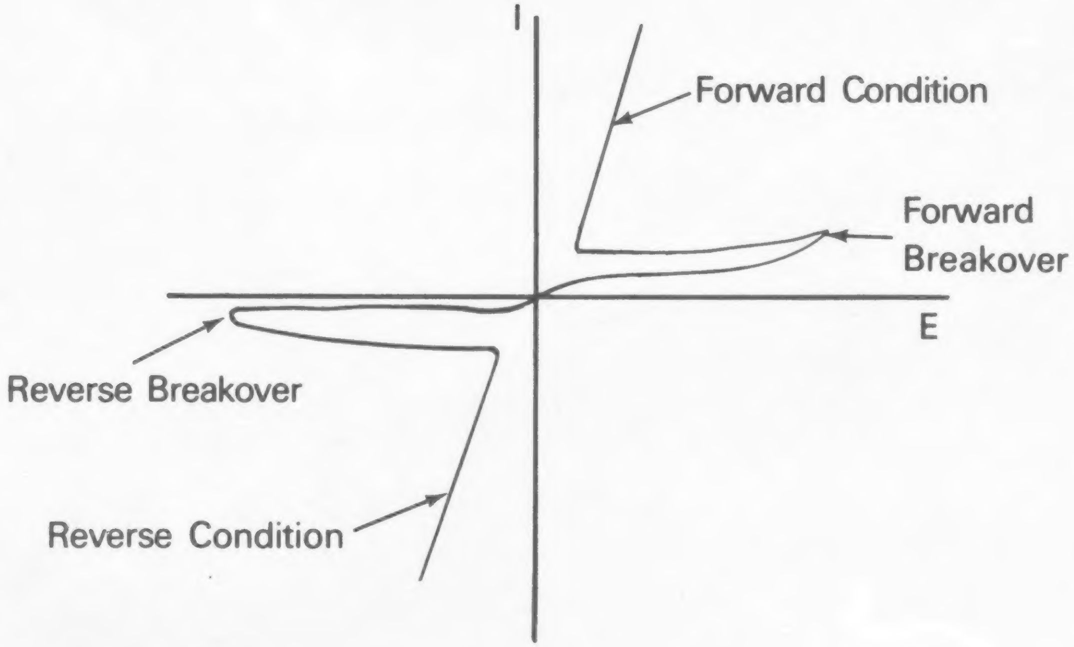


Output Characteristic Curves

Triac

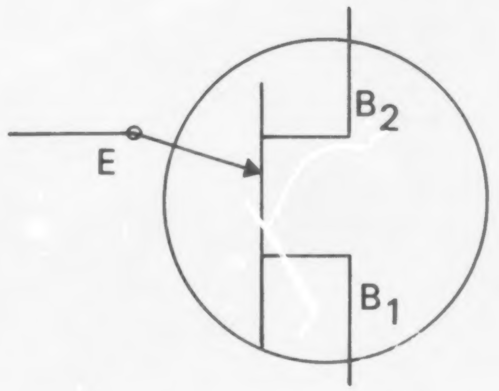


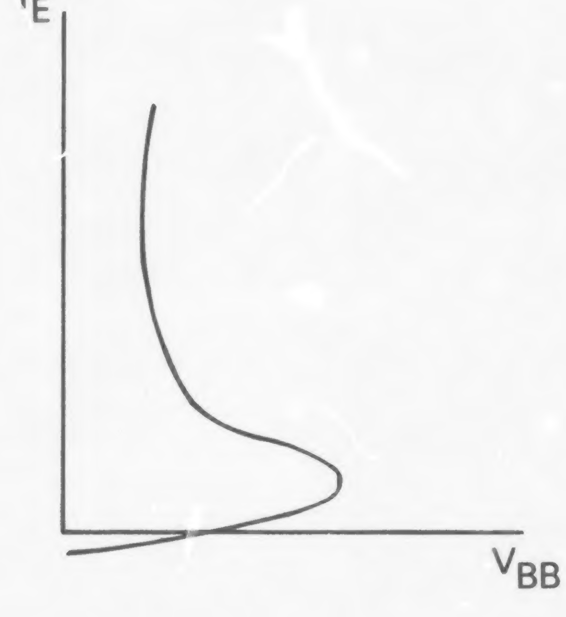
Schematic Symbol



Output Characteristic Curves

Unijunction Transistor

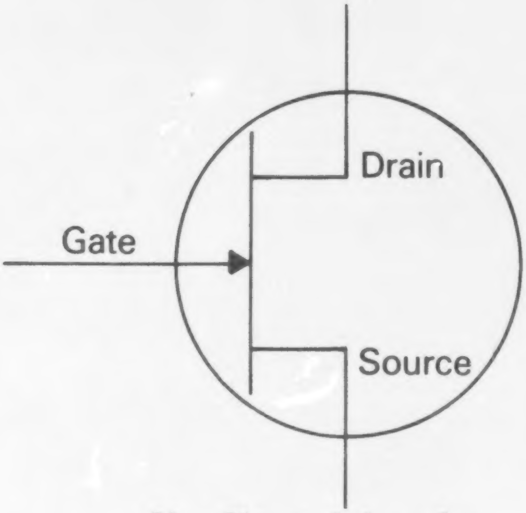




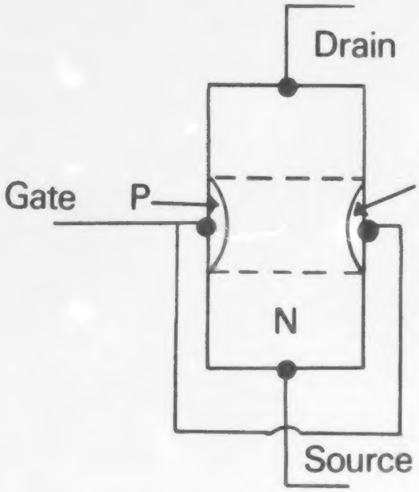
Output Characteristic Curve

Junction Field Effect Transistor

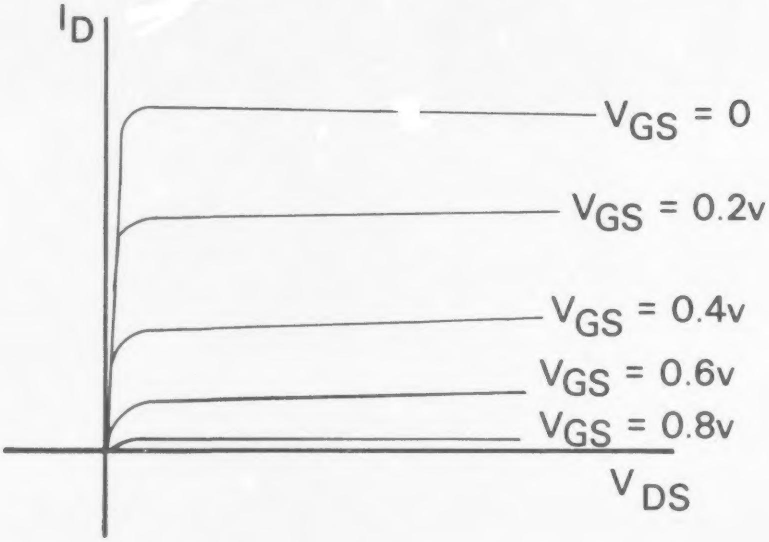
JFET


Drain
Gate
Source

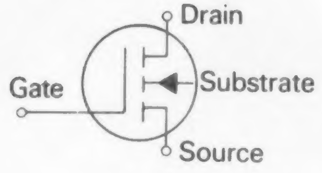
N - Channel Junction
Field Effect Transistor


Drain
Gate
P
P
N
Source

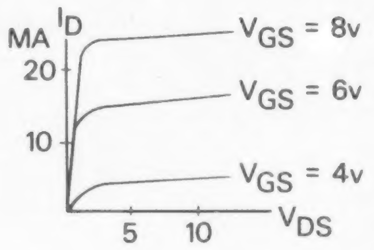
JFET Construction



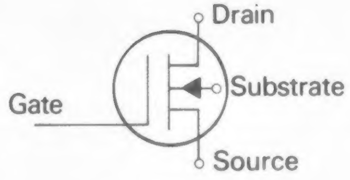
Insulated Gate Field Effect Transistor (IGFET) or Metal Oxide Semiconductor Field Effect Transistor (MOSFET)


Drain
Gate
Substrate
Source

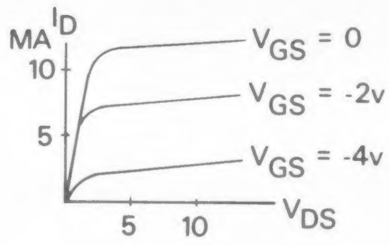
Enhancement Mode
(Type N-Channel)
Schematic Symbol



Output Characteristic Curves

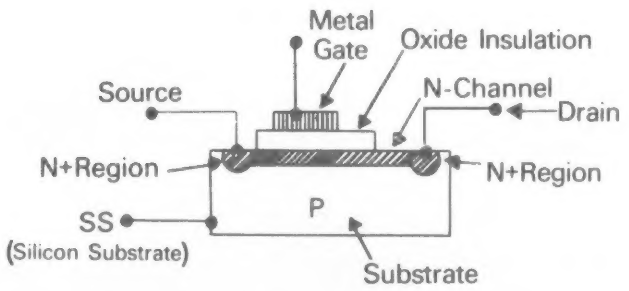

Drain
Gate
Substrate
Source

Depletion Mode
(Type N-Channel)
Schematic Symbol



Output Characteristic Curves

Arrow always points toward the N-type material.


Metal Gate
Oxide Insulation
Source
N-Channel
Drain
N+Region
N+Region
SS
(Silicon Substrate)
P
Substrate

MOSFET Construction – Depletion-Type

SPECIAL SEMICONDUCTOR DEVICES
UNIT XI

JOB SHEET #1--CONSTRUCT AND TEST A SILICON CONTROLLED RECITIFIER CIRCUIT

I. Tools and equipment

   A. GE C106B SCR or equivalent

   B. 6-volt power supply (300 mA)

   C. #328 incandescent lamp and holder or equipment

   D. 1-10k potentiometer

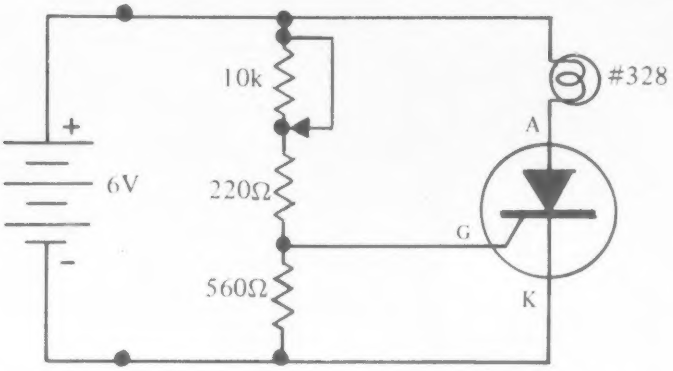
   E. 1-220 ohm resistor

   F. 1-560 ohm resistor

II. Procedure

   A. Connect the circuit as shown below

   (CAUTION: Do not turn on the power supply at this time.)



   B. Adjust the 10k potentiometer for maximum resistance

   C. Turn on power supply

   D. Connect your voltmeter between the gate and cathode leads of the SCR

   E. Slowly decrease the resistance of the 10k potentiometer until the lamp lights; then read and record the gate voltage

   F. Disconnect the gate lead and observe

   G. Replace the gate lead

   H. Return the potentiometer to its maximum resistance position

JOB SHEET #1

I. Place a jumper between the anode and cathode of the SCR, then remove the jumper and observe that the lamp goes out

J. Repeat Steps D through H, and compare the results obtained the second time with those obtained the first time

K. Turn off the power supply, then turn it on again, and observe the lamps

L. Check your results with your instructor

SPECIAL SEMICONDUCTOR DEVICES
UNIT XI

JOB SHEET #2--CONSTRUCT AND TEST A UNIJUNCTION TRANSISTOR RELAXATION OSCILLATOR

I. Equipment and material needed

A. GE 2N2646 UJT or equivalent

B. Power supply (12 volts)

C. 1-10k potentiometer

D. 1-100 ohm resistor

E. 1-470 ohm resistor

F. 1-33 ohm resistor

G. 1-0.1μF capacitor

H. Multimeter

I. Oscilloscope

J. Graph paper

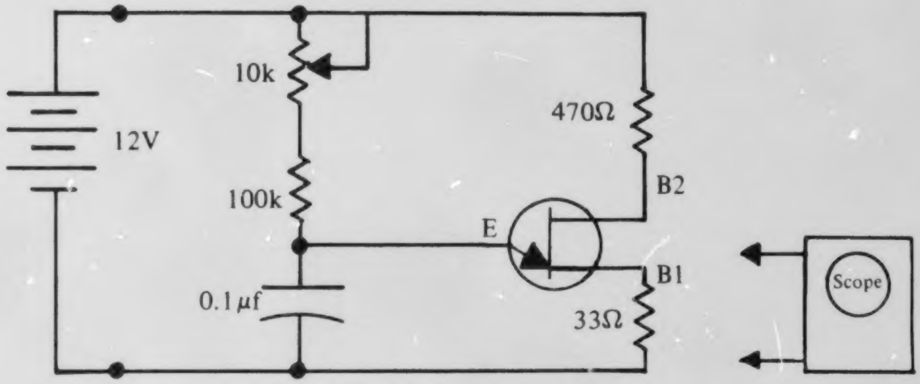
K. Soldering iron or gun

II. Procedure

A. With an ohmmeter, read and record the resistance between the two bases

B. Connect the circuit shown below

(CAUTION: Do not turn on the power supply at this time.)



JOB SHEET #2

C. Place the potentiometer in approximately the midrange position

D. Turn on the power supply

E. Connect the oscilloscope to observe the waveshape across the capacitor and sketch a scale drawing of this voltage waveshape

F. Connect the oscilloscope to observe the waveshape across the 33 ohm resistor and sketch a scale drawing of this voltage waveshape

(NOTE: If your oscilloscope has two channels or if you have an electronic switch, observe the waveshapes of Steps E and F simultaneously. If not, draw your two pictures so you can relate the time on the sketches to each other.)

G. From your sketches determine the frequency of oscillation, that is, the number of pulses per second that are being generated

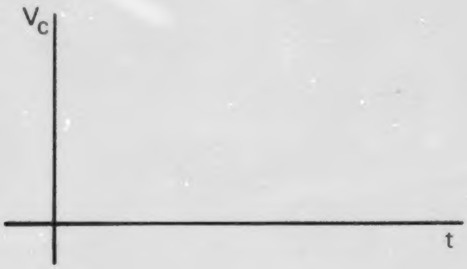
H. Change the potentiometer setting and observe the voltage waveshapes to see if the frequency changes; determine whether frequency increases or decreases when the potentiometer resistance is increased

I. Connect the oscilloscope across the 33 ohm resistor and set the potentiometer approximately to midrange, then while observing the oscilloscope, hold a hot soldering gun near the UJT for three seconds and observe any change

J. Check your results and sketches with your instructor

(NOTE: Record observation from step I.)

$R_{B_1B_2}$ ____________________



$V_{33\Omega}$ ____________________

f = ____________________

(Note: Record observations from step I)

SPECIAL SEMICONDUCTOR DEVICES
UNIT XI

JOB SHEET #3--CONSTRUCT AND TEST A FIELD EFFECT TRANSISTOR AMPLIFIER

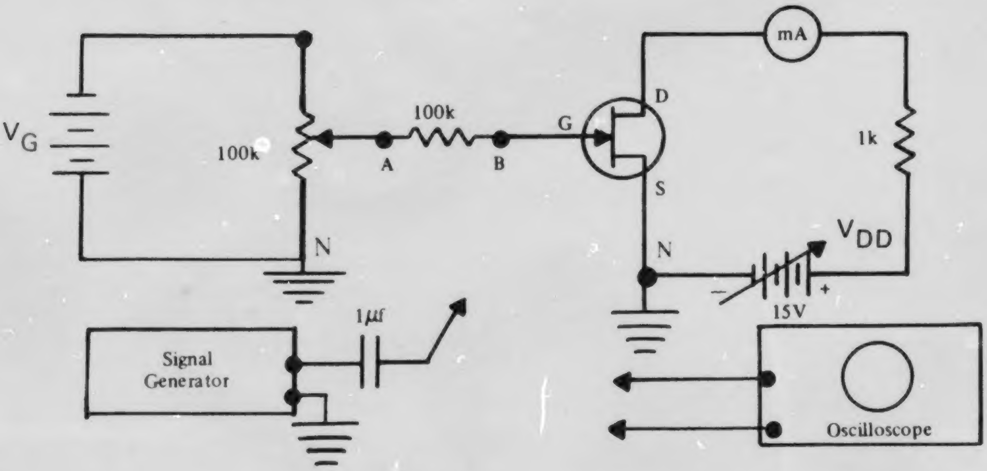
I. Tools and equipment

- A. 2N5555 JFET or equivalent
- B. 2-15 volt power supplies
- C. 1-100k resistor
- D. 1-1k resistor
- E. 1-100k potentiometer
- F. 1-1μF capacitor
- G. Signal generator
- H. Oscilloscope
- I. Multimeter
- J. Milliammeter
- K. Graph paper

II. Procedure

- A. Wire the following circuit

  (CAUTION: Do not turn on the power at this time.)


mA
VG
100k
100k
A
B
G
D
S
1k
N
N
VDD
−
+
15V
1μf
Signal Generator
Oscilloscope

JOB SHEET #3

B. Turn on the drain power supply (V_{DD}) and observe the drain current on the milliammeter meter

C. Turn on the gate power supply (V_G) and observe any change in drain current

D. Adjust the potentiometer until the drain current is barely measurable, then record the voltage at Point A to ground

E. Recheck to see that both power supplies are set to 15 volts (with polarities as shown in the schematic)

F. Adjust the potentiometer until the drain current is at 4 mA, then record the voltage at Point A to ground

G. Adjust the potentiometer until the drain current is at 5 mA, then record the voltage at Point A to ground

H. Short out the milliammeter

I. While reading the drain to source voltage with a multimeter, adjust the potentiometer until the voltage equals +10 volts

J. Connect the signal generator through a 1 μF capacitor to Point B

K. Adjust the signal generator for a signal of 1 kHz, and an amplitude of 0.1 volt peak-to-peak

L. Connect the oscilloscope across the 1k load resistor

M. Record the amplitude of the signal voltage across the load resistor

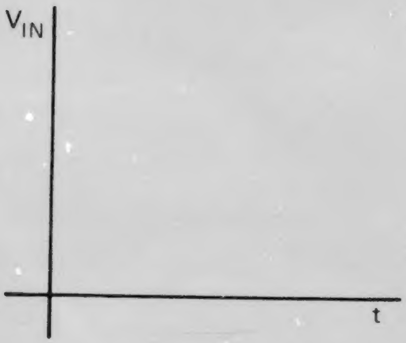
N. Make a scale drawing of both input and output voltage waveshapes

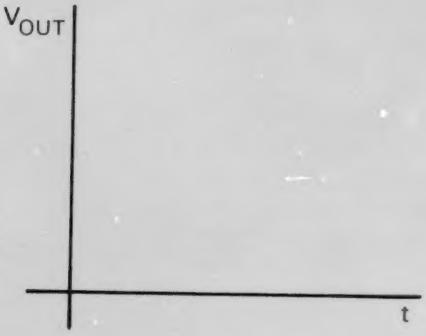
O. Check your results and your drawing with your instructor

JOB SHEET #3

Data Table

I_D	V_{AN}	
Initial		
4mA		
5mA		





SPECIAL SEMICONDUCTOR DEVICES
UNIT XI

JOB SHEET #4–CONSTRUCT AND TEST A THERMISTOR CONTROLLED CIRCUIT

I. Equipment and materials needed

A. Thermister CA31J1 .3 inch disc thermister Ro @ 25°C = 1000 ohms or equivalent

B. DC milliammeter (center scale deflection)

C. 1-4.7k ohm resistor, 1-1k ohm resistor

D. 1-10k ohm potentiometer

E. 1-1K resistor

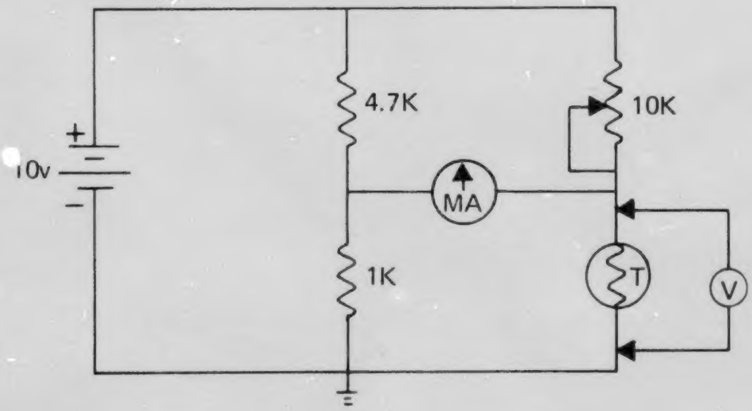
F. DC power supply

G. Multimeter (optional)

H. Soldering iron or some means to heat the thermistor

II. Procedure

A. Connect the circuit shown below



B. Turn the power supply on and adjust to 10 volts then adjust the potentiometer until the meter gives a "0" indication

JOB SHEET #4

C. Measure and record the voltage across the thermister; heat the thermistor with a soldering iron or light bulb and note any change or current through the millimeter; remove the heat source from the thermistor and note any change of current and voltage

Optional

A. Measure the room temperature next to the thermistor before heating the thermistor and record the temperature, current, and the voltage drop across the thermistor

B. Heat the thermistor until you obtain a change in current, then record the new current, the temperature, and the voltage across the thermistor

C. Calculate the thermistor's resistance for both the cold and heated conditions

(NOTE: You may need to review the basic electrical equations for a resistive bridge circuit.)

D. Measure and record the voltage across the thermistor

E. Heat the thermistor with a soldering iron or light bulb and note any change of current through the milliameter

F. Measure and record the voltage drop across the thermistor

G. Remove the heat source from the thermistor and note any change of current and voltage

SPECIAL SEMICONDUCTOR DEVICES
UNIT XI

NAME______________________________

TEST

1. Match the terms on the right with their correct definitions.

______a. A family of multilayered semiconductor devices which are used primarily for switching current

______b. A three-terminal device similar to an ordinary rectifier except its rectifying characteristics can be controlled; a member of the thyristor family

______c. A three-termimal device which is a member of the thrysistor family and is generally applied as an AC switching device

______d. A bidirectional trigger diode

______e. A temperature-sensitive resistor

______f. A specialized type of junction transistor which is normally used as a switching device

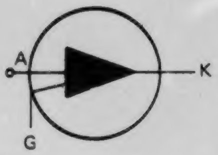
______g. A specialized type of transistor which is voltage controlled and has very high input impedance

______h. A specialized semiconductor device used for switching purposes; it has a trigger voltage that is programmable

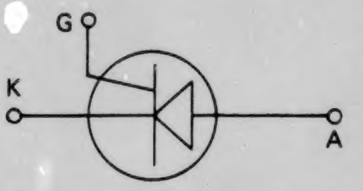
1. UJT
2. Diac
3. PUT
4. Thyristors
5. FET
6. SCR
7. Triac
8. Thermistor

2. Identify the schematic symbol for an SCR by circling the correct letter.

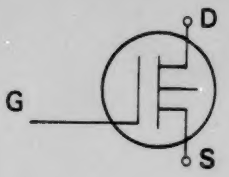
a.



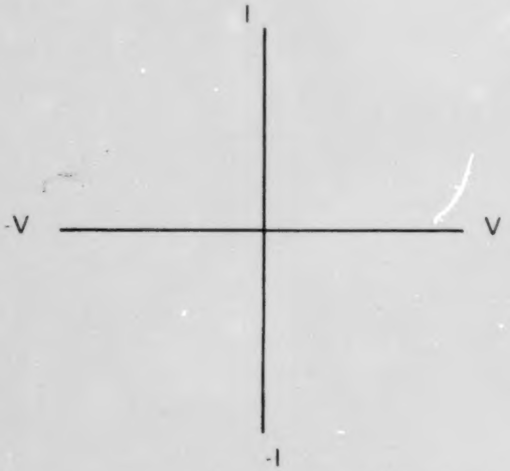
b.



c.



3. Sketch the output characteristic curves of an SCR on the diagram that follows.



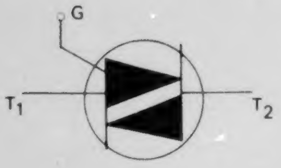
4. Select true statements concerning other characteristics of an SCR by placing an "X" in the appropriate blanks.

_____a. Medium gate current

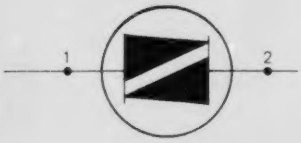
_____b. Remains on until anode to cathode current is reduced below minimum holding current, I_H

5. Identify the schematic symbol for a Triac by circling the correct letter.

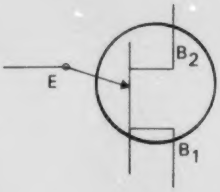
a.



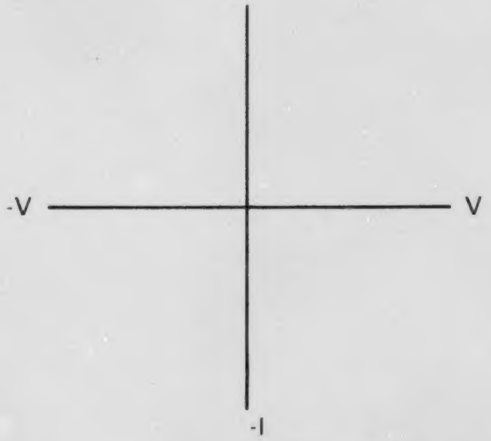
b.



c.

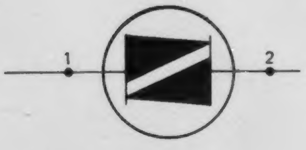


6. Sketch the output characteristic curves of a Triac on the diagram below.

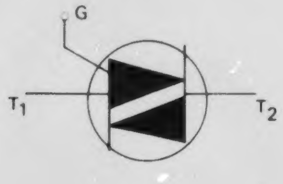


7. Identify the schematic symbol for a Diac by circling the correct letter.

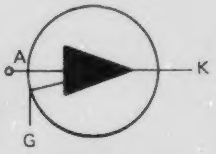
a.



b.



c.



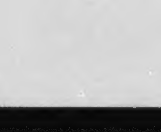
8. Select true statements concerning Diac applications by placing an "X" in the appropriate blanks.

_____a. Used to trigger Triacs

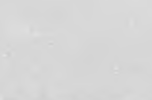
_____b. Used only with extremely low voltages

9. Distinguish between the schematic symbols for directly and indirectly heated thermistors by placing an "X" beneath the schematic for the directly heated thermistor.

a.



b.



10. Select true statements concerning thermistor applications by placing an "X" in the appropriate blanks.

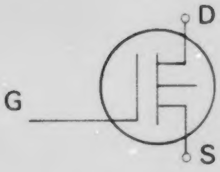
______a. Used when a positive temperature coefficient is required

______b. Detects changes in the temperature of the surroundings

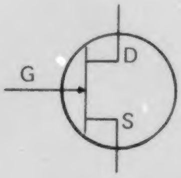
______c. Detects changes in current flow by indirect heating of the device

11. Identify the schematic symbol for a UJT by circling the correct letter.

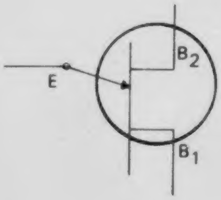
a.



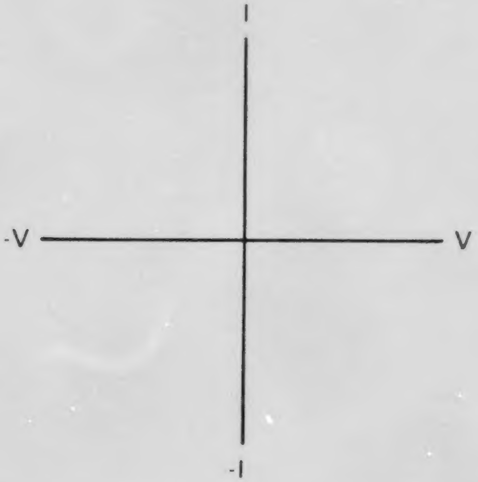
b.



c.



12. Sketch the output characteristic curves of a UJT on the diagram that follows.



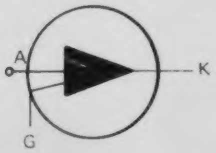
13. Select true statements concerning UJT applications by placing an "X" in the appropriate blanks.

______a. Wave-shaping generators

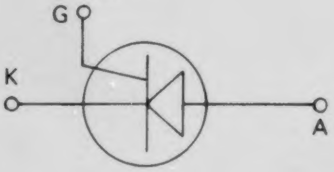
______b. Pulse-forming circuits

14. Identify the schematic symbol for a PUT by circling the correct letter.

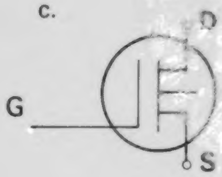
a.



b.



c.



15. Distinguish between the advantages of a PUT over a UJT by placing an "X" beside the statements that indicate PUT advantages.

_____a. Higher breakdown voltage

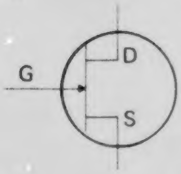
_____b. Low voltage operation capability

_____c. Programmable trigger voltage

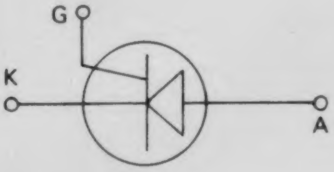
_____d. High cost but small size

16. Identify the schematic symbol for a JFET by circling the correct letter.

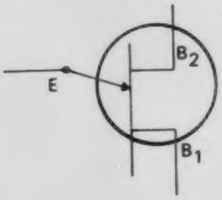
a.



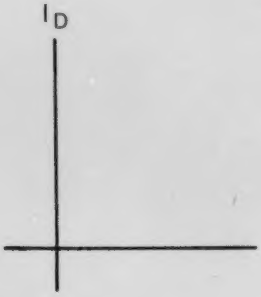
b.



c.

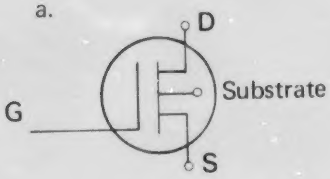


17. Sketch the output characteristic curves of a JFET on the diagram that follows.

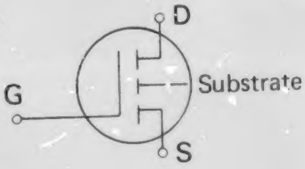


18. Distinguish between the schematic symbols for MOSFETs in the enhancement mode and MOSFETS in the depletion mode by circling the letter beneath the schematic for the MOSFET in the enhancement mode.

a.



b.



19. Select true statements concerning characteristics of IFGETs and MOSFETs by placing an "X" in the appropriate blanks.

_____a. Gate insulated from source and drain

_____b. High input impedance because of the insulation layer

_____c. Enhancement type is normally "on" and has no deposited channel region

_____d. Depletion type is normally "off" and has a deposited channel region

20. Demonstrate the ability to:

a. Construct and test a silicon controlled rectifier circuit.

b. Construct and test a unijunction transistor relaxation oscillator.

c. Construct and test a field effect transistor amplifier.

d. Construct and test a thermistor controlled circuit.

(NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

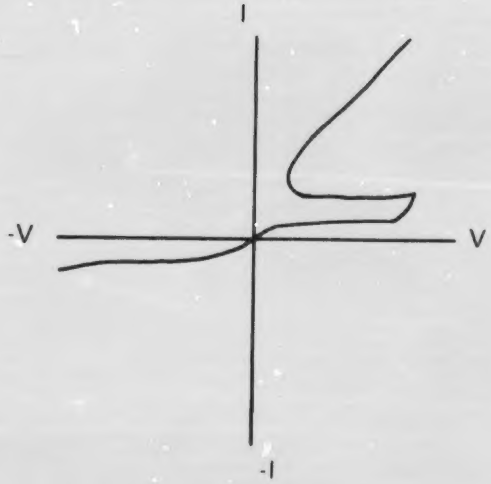
SPECIAL SEMICONDUCTOR DEVICES
UNIT XI

ANSWERS TO TEST

1. a. 4 e. 8
   b. 6 f. 1
   c. 7 g. 5
   d. 2 h. 3

2. b

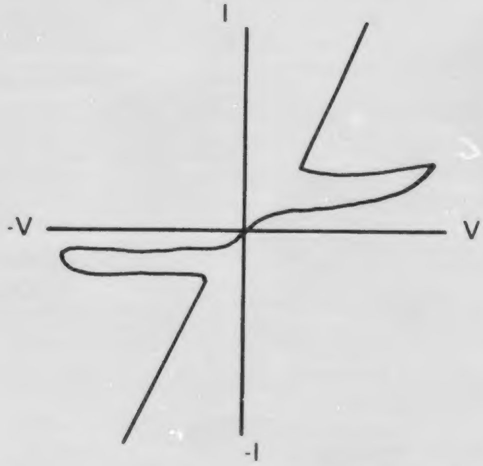
3.



4. b

5. a

6.



7. a

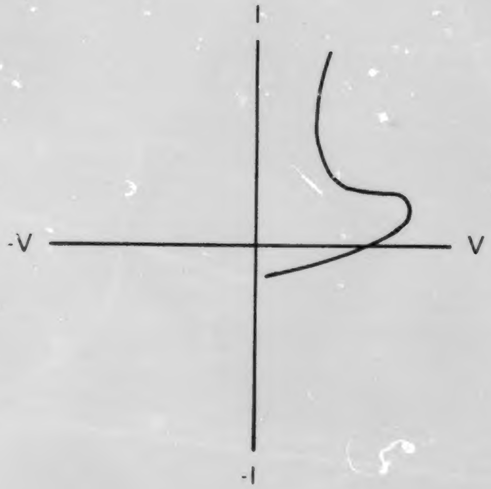
8. a

9. b

10. b, c

11. c

12.



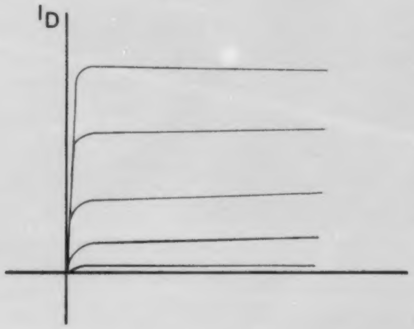
13. a, b

14. a

15. a, b, c

16. a

17.



18. b

19. a, b

20. Performance skills evaluated to the satisfaction of the instructor

OSCILLATORS
UNIT XII

UNIT OBJECTIVE

After completion of this unit, the student should be able to identify the circuit schematic diagrams for various oscillator types and construct and test a Hartley oscillator. This knowledge will be evidenced by correctly performing the procedures outlined in the job sheet and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

1. Match terms related to oscillators with the correct definitions.
2. Identify the circuit schematic diagrams for a Hartley oscillator, a Colpitts oscillator, and a Clapp oscillator.
3. Identify the circuit schematic diagrams for a Pierce oscillator, a TBTC oscillator, and an RC oscillator.
4. Demonstrate the ability to construct and test a Hartley oscillator.

OSCILLATORS
UNIT XII

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information and job sheets.

III. Make transparencies.

IV. Discuss unit and specific objectives.

V. Discuss information sheet.

VI. Demonstrate and discuss the procedures outlined in the job sheets.

VII. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

- A. Objective sheet
- B. Information sheet
- C. Transparency masters
  - 1. TM 1--Hartley, Colpitts, and Clapp Oscillators
  - 2. TM 2--Pierce, TBTC, and RC Oscillators
- D. Job Sheet #1--Construct and Test a Hartley Oscillator
- E. Test
- F. Answers to test

II. References:

A. Millman, Jacob and Christos Halkias. *Electronic Devices and Circuits.* New York: McGraw-Hill Book Company, 1967.

B. Schilling, Donald L. and Charles Belove. *Electronic Circuits: Discrete and Integrated.* New York: McGraw-Hill Book Company, 1979.

OSCILLATORS
UNIT XII

INFORMATION SHEET

I. Terms and definitions

A. Oscillator--An electronic device which converts energy from a DC supply source into AC energy at some specific frequency

B. Feedback--The coupling of energy from the output back to the input of a circuit

C. Resonant frequency (F_o or F_r)--The frequency of oscillation of a tuned circuit

D. LC circuit--One of the classifications of oscillators in which the resonant frequency is determined by the inductor (L) and the capacitor (C) in the circuits

E. RC circuit--One of the classifications of oscillators in which the resonant frequency is determined by the resistance and capacitance in the circuit

F. Crystal circuit--One of the classifications of oscillators in which the resonant frequency is determined by a crystal

II. Oscillators (Transparency 1)

A. Hartley oscillator

1. Common-base or common-emitter type amplifier
2. Tapped inductor
3. Capacitor feedback
4. Used for frequencies up to 160 megahertz

B. Colpitts oscillator

1. Tapped capacitors
2. Resonant frequency determined by the value of the inductor, L, and the series connected value of the two capacitors, C_1 and C_2
3. Capacitor feedback

INFORMATION SHEET

C. Clapp oscillator

1. High degree of frequency stability in a variable-frequency oscillator
2. Inductor replaced by a series resonant circuit
3. Limited operating frequency range
4. Capacitor feedback

III. Oscillators (Transparency 2)

A. Pierce oscillator

1. Uses a fixed-frequency crystal
2. Very stable frequency response, often better than 0.01 percent of center frequency
3. Capacitor feedback

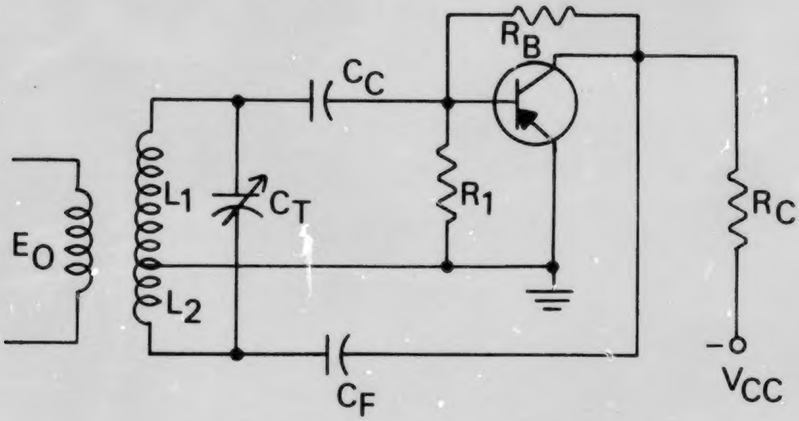
B. TBTC (Tuned Base Tuned Collector) oscillator

1. Uses interelectrode capacitance for a feedback path
2. C_F small capacitance to assure sufficient feedback at all times
3. Capacitor feedback

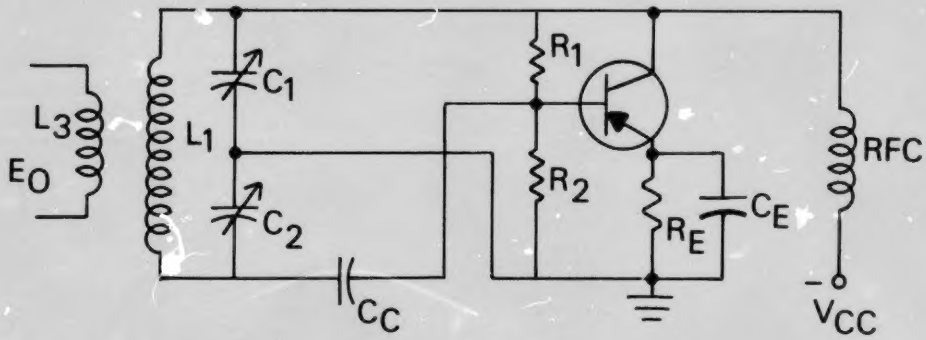
C. RC phase shift oscillator

1. Usually audio-frequency oscillators
2. Considerable power loss
3. Inexpensive to build
4. Capacitor feedback

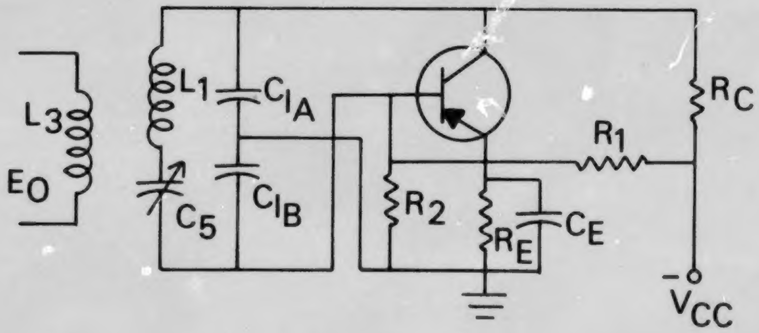
Hartley, Colpitts and Clapp Oscillators


RB
CC
L1
CT
R1
RC
EO
L2
CF
–
VCC

Hartley Oscillator

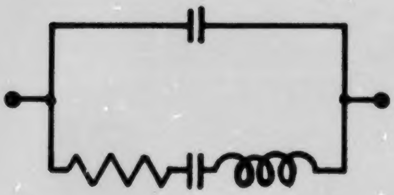

R1
C1
L3
L1
EO
R2
RFC
CE
C2
RE
CC
–
VCC

Colpitts Oscillator

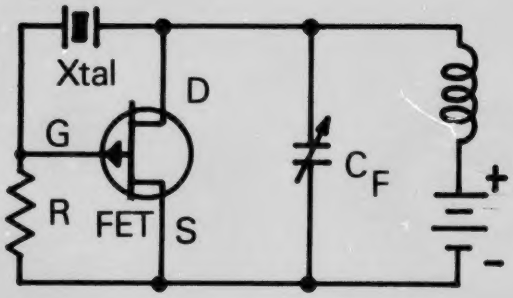

L1
CIA
RC
L3
R1
EO
C5
CIB
R2
CE
RE
–
VCC

Clapp Oscillator

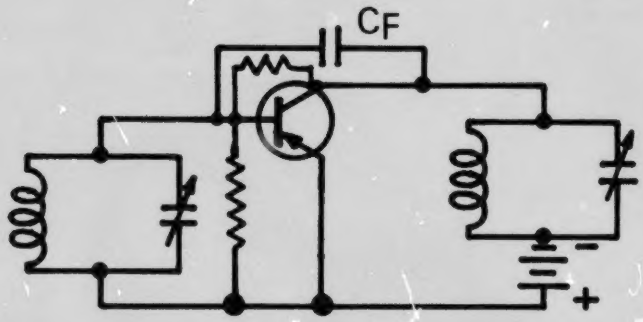
Pierce, TBTC and RC Oscillators



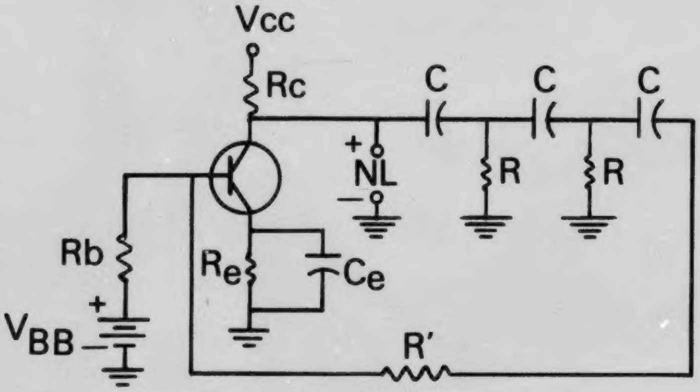
Crystal Equivalent Circuit


Xtal
D
G
R
FET
S
C_F
+
-

Pierce Oscillator



Tuned–Base–Tuned –Collector Oscillator (TBTC)


Vcc
Rc
C
C
C
+
NL
-
R
R
Rb
Re
Ce
+
V_{BB}
-
R'

RC Phase Shift Oscillator

OSCILLATORS
UNIT XII

JOB SHEET #1--CONSTRUCT AND TEST A HARTLEY OSCILLATOR

I. Tools and equipment

A. 2N3638 PNP transistor or equivalent

B. 2mH RF transformer

C. 1 - 0.1 μF variable capacitor

D. 1 - 0.1 μF capacitor

E. 1 - 0.5 μF capacitor

F. 1 - 1K resistor

G. 1 - 2K resistor

H. 1 - 6.2K resistor

I. Oscilloscope

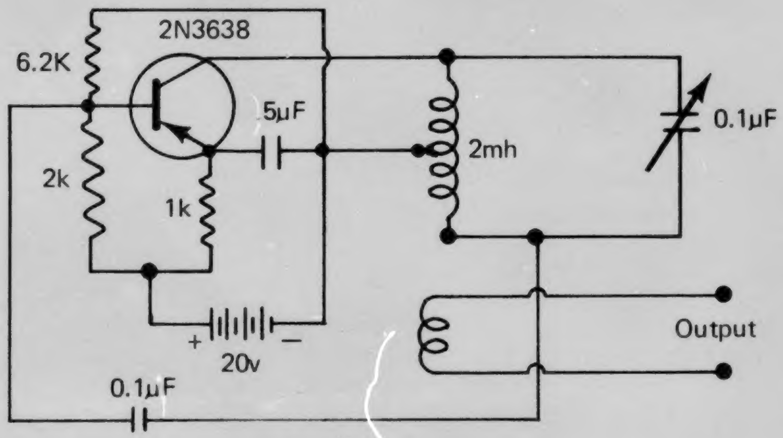
J. DC power supply (0-25V)

K. Frequency counter (optional)

II. Procedure

A. Wire the following circuit

(CAUTION: Do not turn on power supply at this time.)



B. Connect the oscilloscope to the output winding of the RF transformer

JOB SHEET #1

C. Turn on the power supply and observe the waveshape

D. Adjust the variable capacitor and observe the change in frequency

E. Measure the lowest frequency obtainable by adjusting the variable capacitor and the peak-to-peak voltage output

F. Measure (using the oscilloscope) the highest frequency obtainable and the peak-to-peak output voltage

G. With the oscillator operating at its highest frequency, place your finger on the transistor until you observe a change in frequency caused by the slight heating of the transistor

H. Turn off the power supply and replace the transistor with another 2N3638 PNP transistor

I. Turn on the power supply and notice the changes that occur in the output frequency or the output voltage level

J. Check your findings with your instructor

OSCILLATORS
UNIT XII

NAME ______________________________

TEST

1. Match the terms on the right with their correct definitions.

_____a. The frequency of oscillation of a tuned circuit

_____b. An electronic device which converts energy from a DC supply source into AC energy at some specific frequency

_____c. One of the classifications of oscillators in which the resonant frequency is determined by a crystal

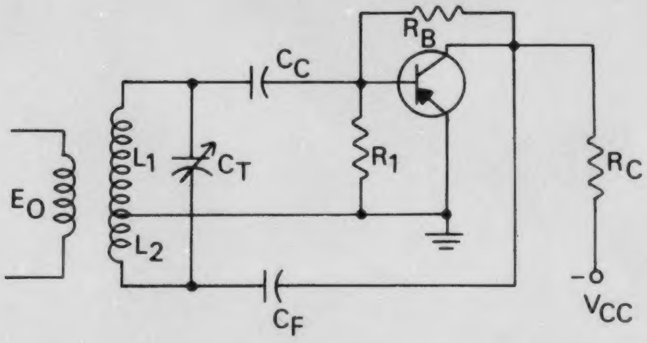
_____d. The coupling of energy from the output back to the input of a circuit

_____e. One of the classifications of oscillators in which the resonant frequency is determined by the inductor and the capacitor in the circuits

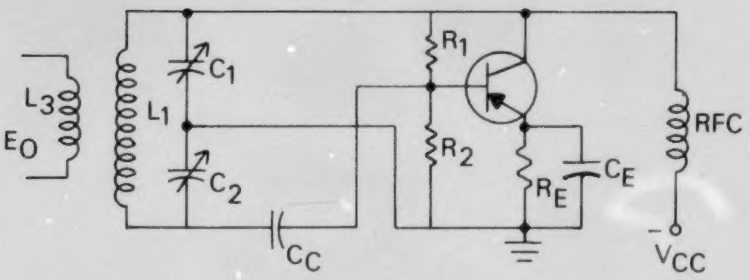
_____f. One of the classifications of oscillators in which the resonant frequency is determined by the resistance and capacitance in the circuit

1. Oscillator
2. Feedback
3. Resonant frequency
4. LC circuit
5. RC circuit
6. Crystal circuit

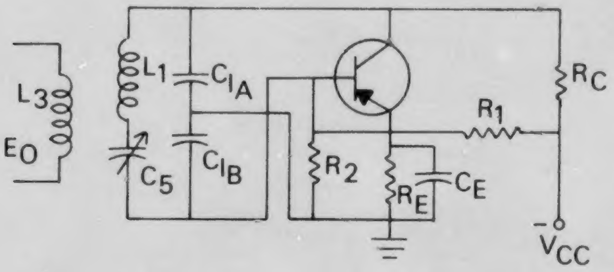
2. Identify a Hartley oscillator, a Colpitts oscillator, and a Clapp oscillator from the schematics that follow.



a. ______________________________

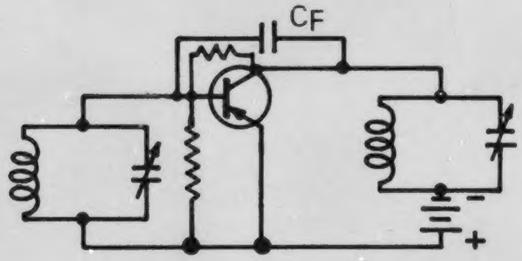

L3
EO
L1
C1
C2
CC
R1
R2
RE
CE
RFC
−
VCC

b. ______________________________

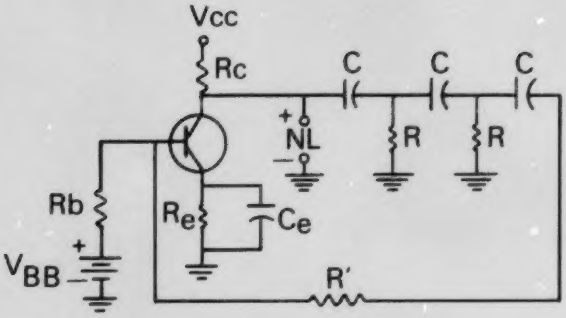

L3
EO
L1
C1A
C1B
C5
R2
RE
CE
R1
RC
−
VCC

c. ______________________________

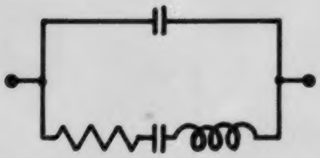
3. Identify a Pierce oscillator, a TBTC oscillator, and an RC oscillator from the schematics that follow.

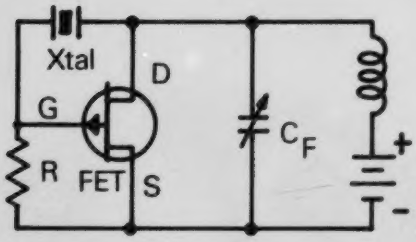


a. ______________________________


Vcc
Rc
C
C
C
+
NL
–
R
R
Rb
Re
Ce
+
VBB
–
R′

b. ______________________________




Xtal
D
G
R
FET
S
CF
+
–

c. ______________________________

4. Demonstrate the ability to construct and test a Hartley oscillator.

(NOTE: If this activity has not been accomplished prior to test, ask your instructor when it should be completed.)

OSCILLATORS
UNIT XII

ANSWERS TO TEST

1. a. 3
   b. 1
   c. 6
   d. 2
   e. 4
   f. 5

2. a. Hartley
   b. Colpitts
   c. Clapp

3. a. TBTC
   b. RC
   c. Pierce

4. Performance skills evaluated to the satisfaction of the instructor

TRANSMITTERS
UNIT XIII

UNIT OBJECTIVE

After completion of this unit, the student should be able to identify the various stages of CW, AM, FM, TV transmitters, and those found in a television transmitting system. The student should also be able to calculate wavelength and antenna length for various types of antennas. This knowledge will be evidenced by correctly performing the procedures outlined in the assignment sheet and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

1. Match terms related to transmitters with their correct definitions.
2. Identify the stages found in a CW transmitter.
3. Identify the stages found in an AM broadcast transmitter.
4. Identify the stages found in an FM broadcast transmitter.
5. Identify the stages found in a television transmitting system.
6. Select true statements concerning the characteristics of antennas.
7. Calculate wavelength and antenna length.

TRANSMITTERS
UNIT XIII

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information and assignment sheets.

III. Make transparencies.

IV. Discuss unit and specific objectives.

V. Discuss information and assignment sheet.

VI. Tour a transmitting facility if possible.

VII. Give test.

INSTRUCTIONAL MATERIALS

I. Objective sheet

  A. Objective sheet

  B. Information sheet

  C. Transparency masters

    1. TM 1--Continuous Wave Transmitter

    2. TM 2--AM Transmitter

    3. TM 3--FM Transmitter

    4. TM 4--Television Transmitting System

  D. Assignment Sheet #1--Calculate Wavelength and Antenna Length

  E. Answers to assignment sheet

  F. Test

  G. Answers to test

TRANSMITTERS
UNIT XIII

INFORMATION SHEET

I. Terms and definitions

   A. Transmitter--A device that converts messages into electrical signals which are sent on a wire or radiated through space from an antenna

   B. Modulation--The process by which the message signal is used to vary some characteristic of a carrier signal, such as amplitude, frequency, or phase

   C. AM (amplitude modulation)--The process by which the message signal is used to vary the amplitude of the carrier signal

   D. FM (frequency modulation)--The process by which the message signal is used to vary the frequency of the carrier signal

   E. CW (continuous wave) transmitter--The system for sending a message signal by turning the RF carrier on and off

   F. Broadcast transmitter (FM or AM)--The system for sending a message signal by modulating the RF carrier

   G. Television transmitter--A system which uses FM to transmit the audio message signal and AM to transmit the video message signal

   H. Antenna--A device which radiates into space the power delivered to it from the transmitter

   I. RF--Radio frequency

II. CW transmitter stages (Transparency 1)

   A. RF oscillator

   B. RF amplifier (buffer)

   C. Power amplifier

III. AM broadcast transmitter stages (Transparency 2)

   A. Audio amplifier

   B. Modulating signal amplifier

   C. RF oscillator

   D. Power amplifier

INFORMATION SHEET

IV. FM broadcast transmitter stages (Transparency 3)

   A. Audio amplifier

   B. Crystal oscillator

   C. Modulator

   D. Frequency multipliers

   E. Power amplifier

V. Television transmitting system stages (Transparency 4)

   A. Sync generators

   B. Camera and camera circuits

   C. Video amplifier

   D. Line and control amplifier

   E. Modulator

   F. RF power amplifier

   G. FM transmitter

VI. Antennas

   A. Wavelength

      1. Greek symbol lambda λ

      2. $\lambda = c/f$ where c is the velocity of light in m/sec and f is frequency in hertz; $C = 3 \times 10^8$ m/sec; therefore, $\lambda = 3 \times 10^8/f$

      (NOTE: λ is in meters and f is the frequency in megahertz.)

   B. Hertz antenna (Figure 1)

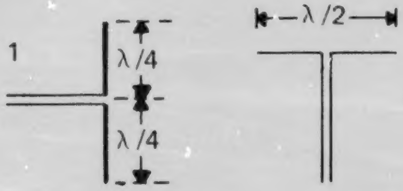
      1. One-half wavelength long

      2. Also called a half-wave dipole antenna

INFORMATION SHEET

3. Does not need to be connected to an earth ground

FIGURE 1



C. Marconi antenna (Figure 2)

1. A grounded antenna

2. Length is "one-fourth wave" or any odd multiple of one-fourth wavelength

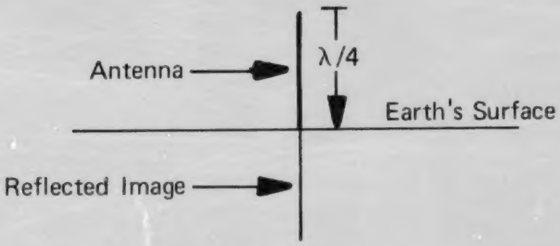
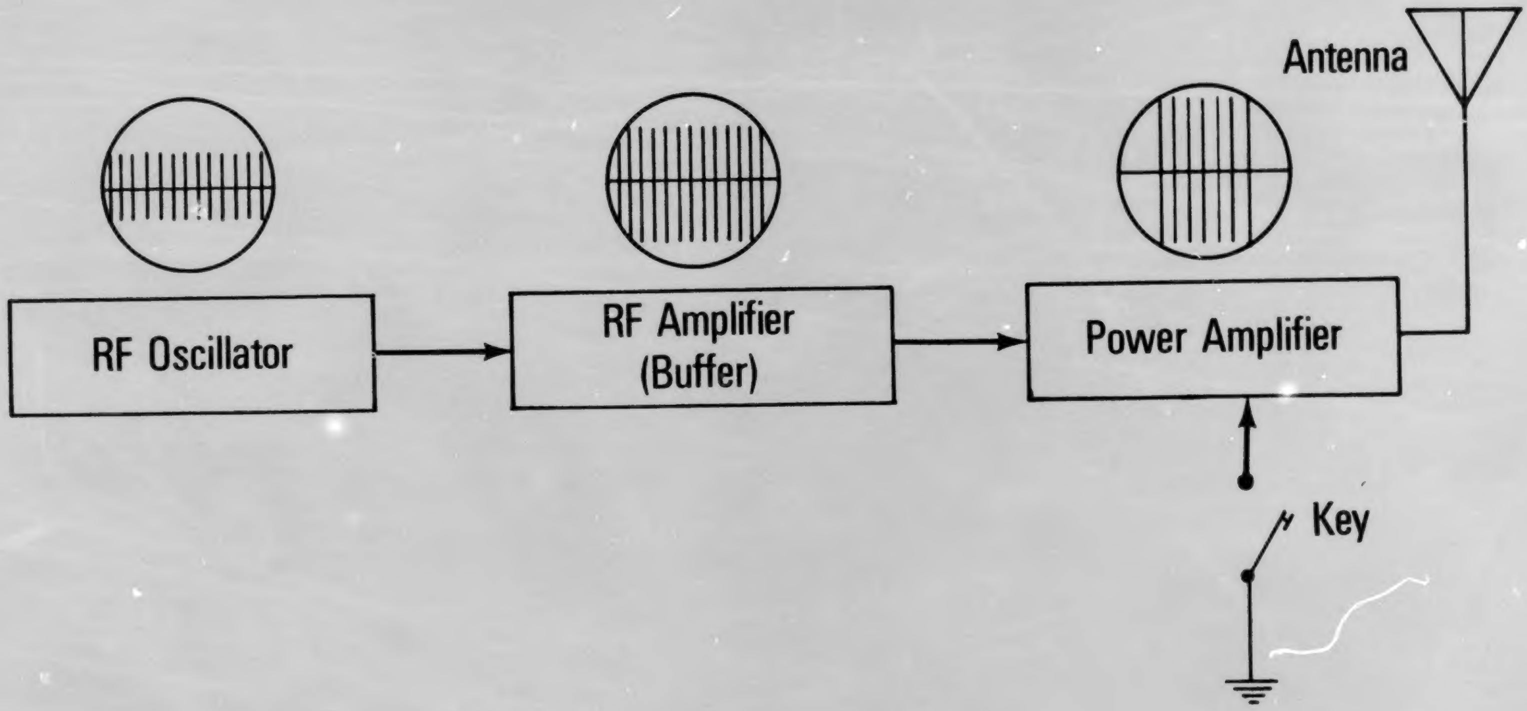

Antenna
λ/4
Earth's Surface
Reflected Image

FIGURE 2

Continuous Wave Transmitter



RF Oscillator

RF Amplifier (Buffer)

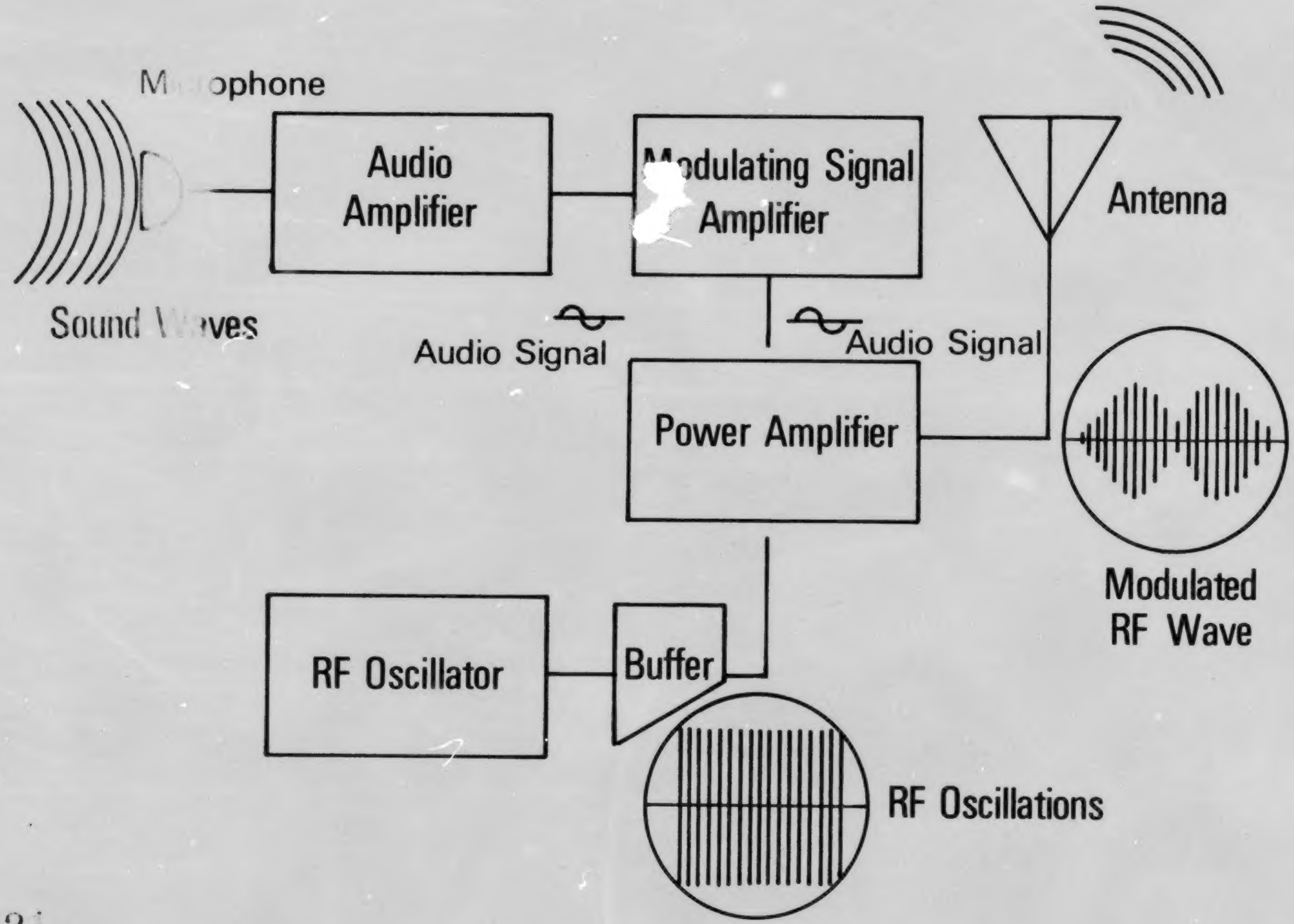
Power Amplifier

Antenna

Key

Block Diagram

AM Transmitter



Microphone

Sound Waves

Audio Amplifier

Audio Signal

Modulating Signal Amplifier

Audio Signal

Antenna

Power Amplifier

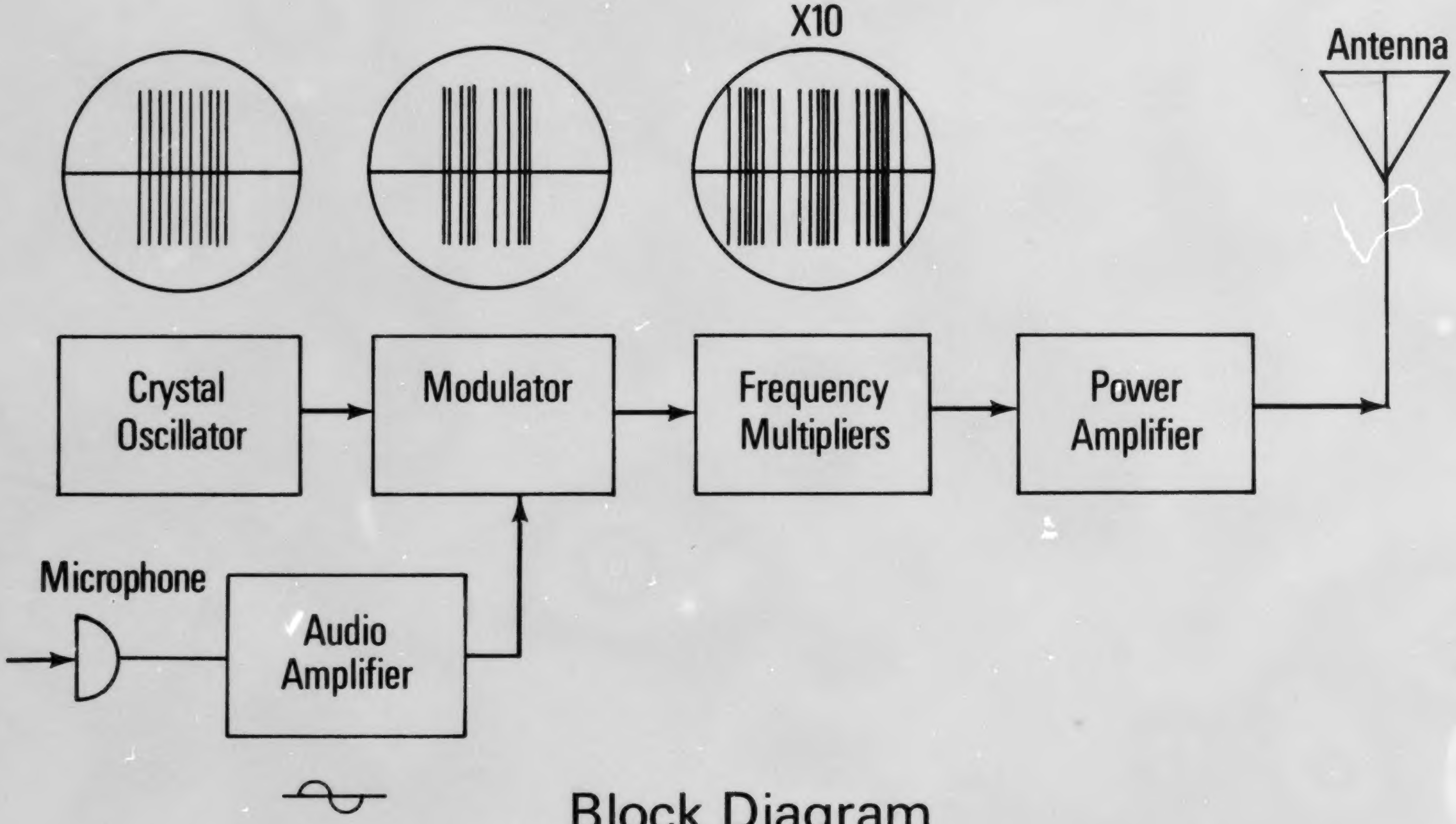
Modulated RF Wave

RF Oscillator

Buffer

RF Oscillations

FM Transmitter



X10

Antenna

Crystal Oscillator

Modulator

Frequency Multipliers

Power Amplifier

Microphone

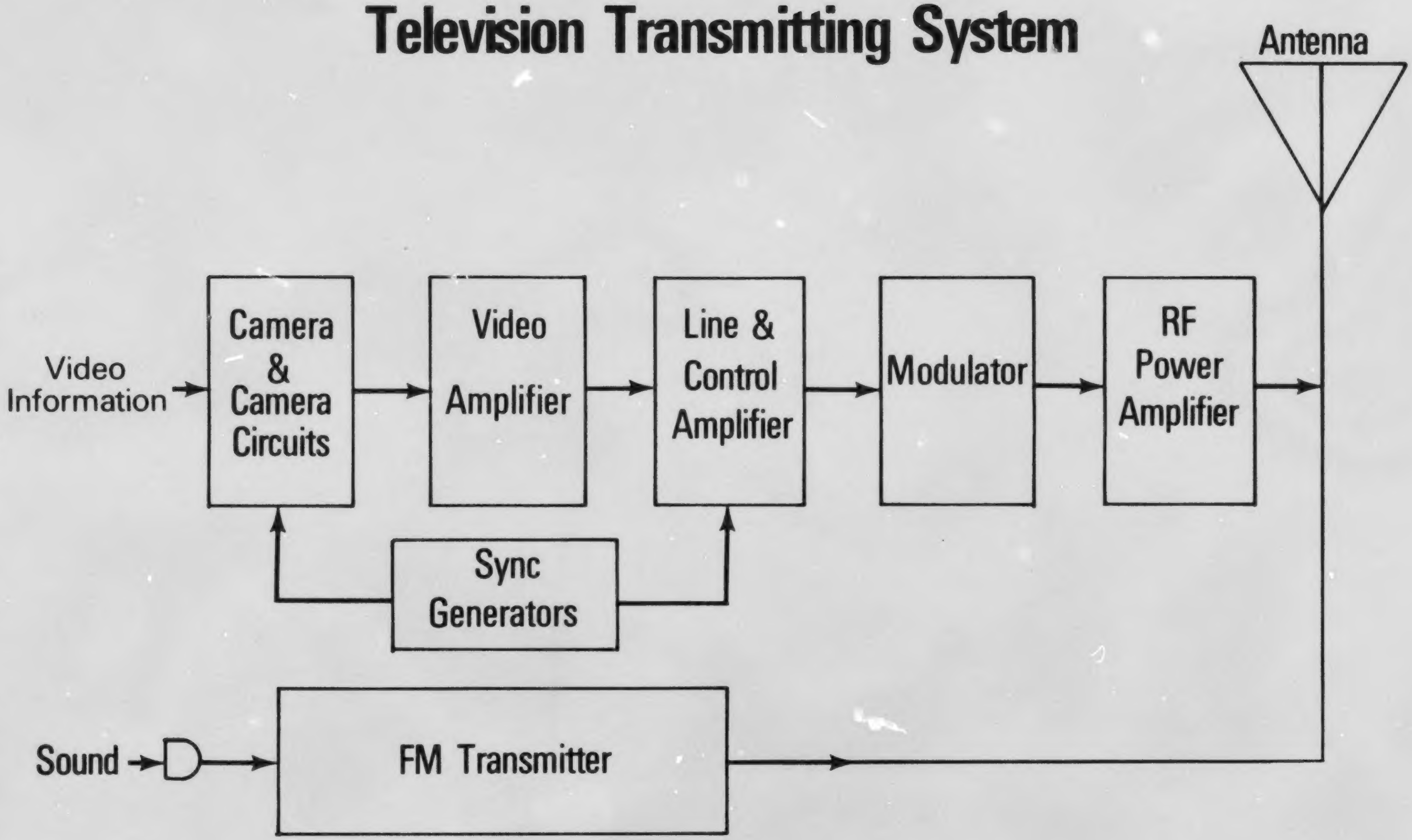
Audio Amplifier

Block Diagram

TM 3

BE II - 401

Television Transmitting System


Antenna
Video Information
Camera & Camera Circuits
Video Amplifier
Line & Control Amplifier
Modulator
RF Power Amplifier
Sync Generators
Sound
FM Transmitter

Block Diagram

TRANSMITTERS
UNIT XIII

ASSIGNMENT SHEET #1--CALCULATE WAVELENGTH AND ANTENNA LENGTH

1. Calculate the wavelength (λ) for a signal.

   (NOTE: Frequency = 1 MHz.)

   λ = ______________________________ meters

2. Calculate the length of a marconi and a hertz antenna.

   (NOTE: There will be resonance at this frequency.)

   a. Hertz antenna length = ______________________________ meters

   b. Marconi antenna length = ______________________________ meters

TRANSMITTERS
UNIT XIII

ANSWERS TO ASSIGNMENT SHEET

1. $\lambda = 300/1 = 300$ meters
2. a. Hertz = $\lambda/2 = 300/2 = 150$ meters

   b. Marconi = $\lambda/4 = 300/4 = 75$ meters

TRANSMITTERS
UNIT XIII

NAME ______________________________

TEST

1. Match the terms on the right with their definitions.

_____a. A device that converts messages into electrical signals which are sent on a wire or radiated through space from an antenna

_____b. The process by which the message signal is used to vary some characteristic of a carrier signal, such as amplitude, frequency, or phase

_____c. The process by which the message signal is used to vary the frequency of the carrier signal

_____d. The process by which the message signal is used to vary the amplitude of the carrier signal

_____e. The system for sending a message signal by turning the RF carrier on and off

_____f. The system for sending a message signal by modulating the RF carrier

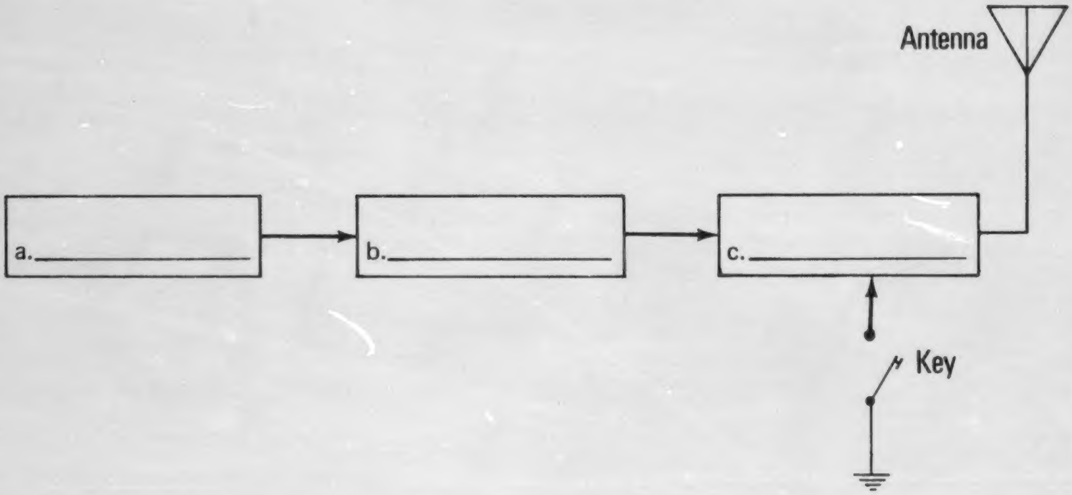
_____g. A system which uses FM to transmit the audio message signal and AM to transmit the video message signal

_____h. A device which radiates into space the power delivered to it from the transmitter

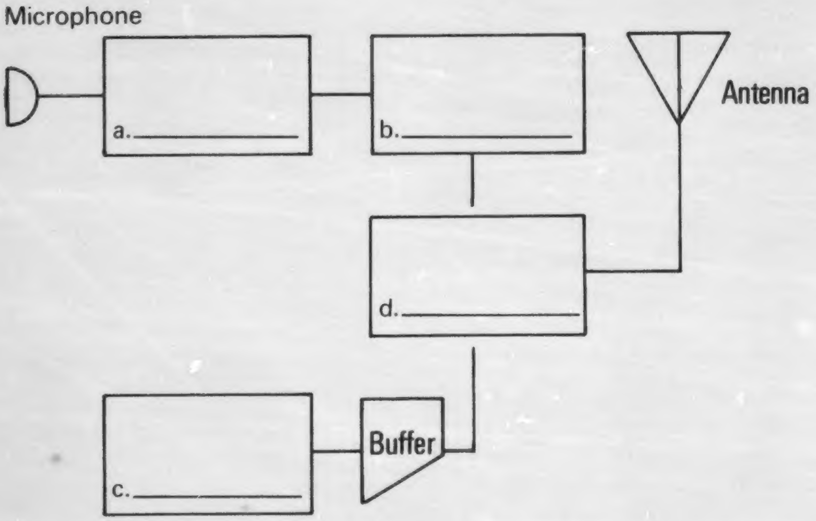
_____i. Radio frequency

1. Antenna
2. Modulation
3. CW transmitter
4. AM
5. Broadcast transmitter
6. FM
7. Television transmitter
8. Transmitter
9. RF

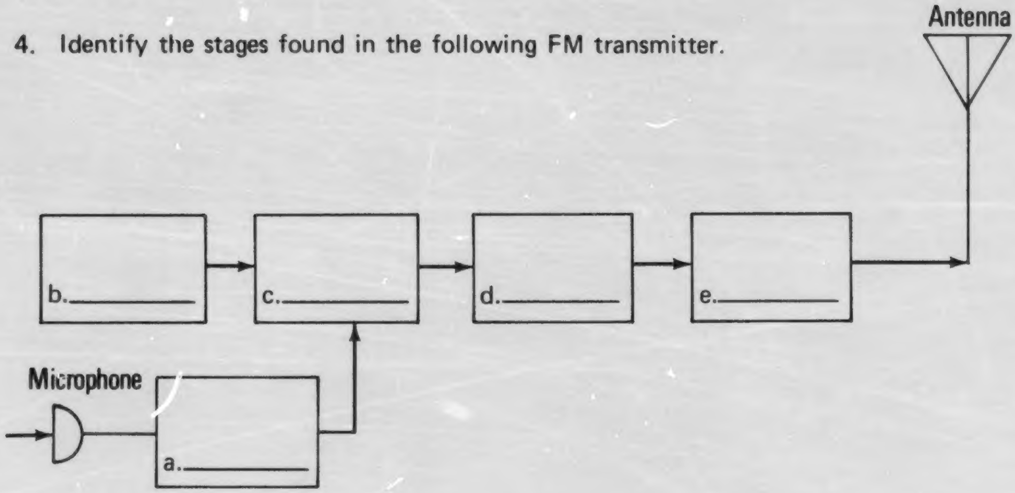
2. Identify the stages found in the following CW transmitter.


Antenna
a.
b.
c.
Key

3. Identify the stages found in the following AM broadcast transmitter.


Microphone
a.
b.
Antenna
d.
c.
Buffer

4. Identify the stages found in the following FM transmitter.

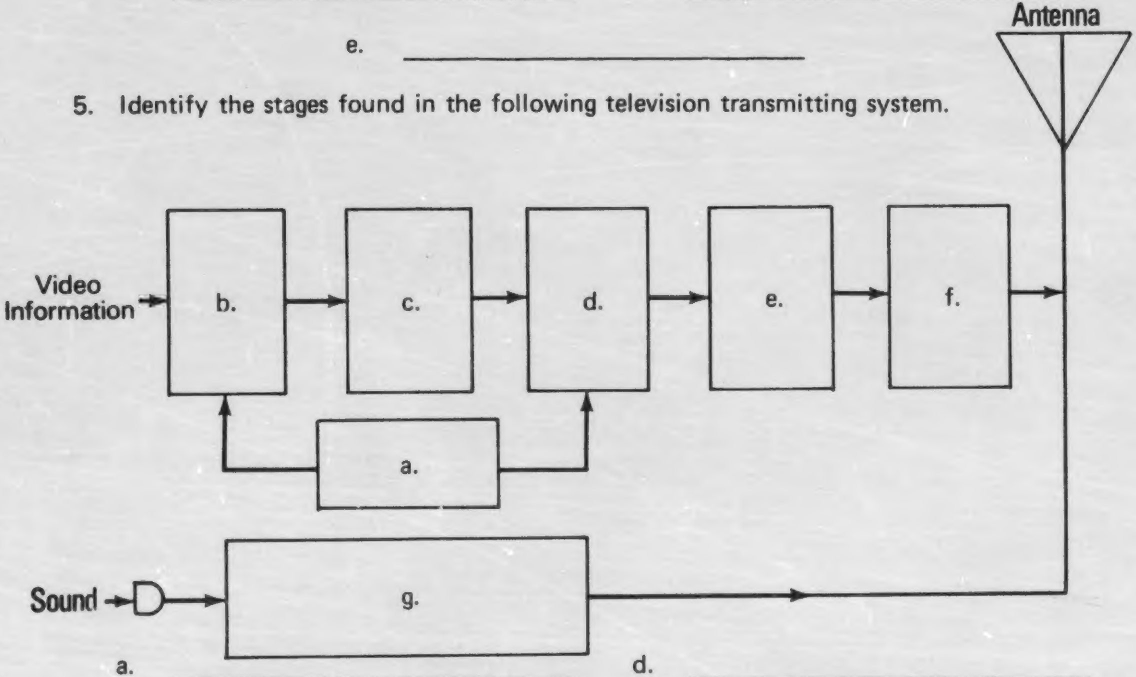

Antenna
b.
c.
d.
e.
Microphone
a.

a. ______________________ c. ______________________

b. ______________________ d. ______________________

e. ______________________

5. Identify the stages found in the following television transmitting system.


Antenna
Video Information
b.
c.
d.
e.
f.
a.
Sound
g.

a. ______________________ d. ______________________

b. ______________________ e. ______________________

c. ______________________ f. ______________________

g. ______________________

6. Select true statements concerning the characteristics of antennas by placing an "X" in the appropriate blanks.

   ______a. The Greek symbol lambda equals c/f where c is the velocity of light in m/sec and f is frequency in hertz

   ______b. The hertz antenna is also called a full-wave dipole antenna

   ______c. The hertz antenna does not need to be connected to an earth ground

   ______d. The Marconi antenna is a grounded antenna

   ______e. The Marconi antenna is "one-fourth wave" or any odd multiple of one-fourth wavelength

7. Calculate wavelength and antenna length.

   (NOTE: If this activity has not been accomplished prior to the test, ask your instructor when it should be completed.)

TRANSMITTERS
UNIT XIII

ANSWERS TO TEST

1. a. 8
   b. 2
   c. 6
   d. 4
   e. 3
   f. 5
   g. 7
   h. 1
   i. 9

2. a. RF oscillator
   b. RF amplifier
   c. Power amplifier

3. a. Audio amplifier
   b. Modulating signal amplifier
   c. RF oscillator
   d. Power amplifier

4. a. Audio amplifier
   b. Crystal oscillator
   c. Modulator
   d. Frequency multipliers
   e. Power amplifier

5. a. Sync generators
   b. Camera and camera circuits
   c. Video amplifier
   d. Line and control amplifier
   e. Modulator
   f. RF power amplifier
   g. FM transmitter

6. a, c, d, e

7. Evaluated to the satisfaction of the instructor

RECEIVERS
UNIT XIV

UNIT OBJECTIVE

After completion of this unit, the student should be able to locate and identify the major stages of AM and FM receivers. This knowledge will be evidenced by correctly performing the procedures outlined in the job sheet and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to receivers with the correct definitions.
2. Identify the stages in an AM superheterodyne receiver.
3. Identify the stages in an FM receiver.
4. Select the frequency ranges for AM and FM broadcast stations.
5. Select true statements concerning the responsibilities of the FCC.
6. Select true statements concerning the RF amplifier stage in AM and FM receivers.
7. State the output frequencies of the mixer stage given the frequency of the RF signal and the local oscillator frequency.
8. Select true statements concerning the IF amplifier stage of AM and FM receivers.
9. Select true statements concerning the AM detector stage.
10. Select true statements concerning the limiter stage in an FM receiver.
11. Select true statements concerning an FM detection circuit.
12. Demonstrate the ability to locate and identify the major stages of AM/FM receivers.

RECEIVERS
UNIT XIV

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information and job sheets.

III. Make transparencies.

IV. Discuss unit and specific objectives.

V. Discuss information sheet.

VI. Demonstrate and discuss the procedures outlined in the job sheet.

VII. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:
  A. Objective sheet
  B. Information sheet
  C. Transparency masters
    1. TM 1--AM Superheterodyne Receiver Block Diagram
    2. TM 2--FM Receiver Block Diagram
  D. Job Sheet #1--Locate and Identify the Major Stages of AM/FM Receivers
  E. Test
  F. Answers to test

II. References:
  A. *The Radio Amateur's Handbook*. Hartford, CT: American Radio Relay League, 1962.
  B. DeFrance, J.J. *Communications Electronics Circuits*. New York: Holt, Rinehart, Winston Publishing Co., 1966.

RECEIVERS
UNIT XIV

INFORMATION SHEET

I. Terms and definitions

A. Receiver--Selects a particular signal that is present on an antenna, removes the carrier frequency, and amplifies the message signal enough to drive a load (speaker or headphones)

B. AM receiver--A receiver designed to receive an amplitude-modulated signal

C. FM (frequency modulated) receiver--A receiver designed to receive a frequency-modulated signal

D. Selectivity--The ability of a receiver to select one signal and reject all others

E. Sensitivity--The ability of a receiver to amplify a small signal

F. RF frequencies--Those frequencies designated as carrier frequencies for radio systems (3 kilohertz to 3,000,000 megahertz)

G. Local oscillator--Stage which produces an unmodulated variable RF signal

H. Mixer--Modulates or heterodynes the RF signal from the antenna (RF amplifier) with the local oscillator RF signal

I. IF (intermediate frequency)--The frequency that results from mixing an RF signal from the amplifier with the local oscillator RF signal; it is then amplified by the IF amplifier

J. Detector--Stage in a receiver that separates the IF frequency from the message signal

(NOTE: A detector is also called a demodulator.)

K. Audio amplifier--The amplifier designed to amplify the message portion of the signal

L. Limiter--Removes or clips the upper and lower amplitude portions of the signal waveshape which removes most of the noise in an FM receiver

M. Discriminator--Separates the IF from the message signal in an FM receiver

N. AVC/AGC (automatic volume/gain control)--Increases the gain of a receiver when the signal becomes weak and decreases the gain of the receiver when the signal becomes strong

O. AFC (automatic frequency control)--Assures a constant IF center frequency by keeping the local oscillator frequency separated from the RF amplifier signal by a fixed amount in FM receivers

INFORMATION SHEET

- P. Converter--Stage which combines both local oscillator and mixer stages into one stage

II. Stages in an AM superheterodyne receiver (Transparency 1)

- A. Antenna
- B. RF amplifier
- C. Mixer
- D. Local oscillator
- E. IF amplifier
- F. Detector
- G. Audio amplifier
- H. Speaker

III. Stages in an FM receiver (Transparency 2)

- A. Antenna
- B. RF amplifier
- C. Mixer
- D. Local oscillator
- E. Wide band IF amplifier
- F. Limiter
- G. Discriminator
- H. AF amplifier
- I. Speaker

IV. AM and FM broadcast station frequency ranges

- A. AM--535 kilohertz to 1605 kilohertz
- B. FM--88 megahertz to 108 megahertz

V. FCC (Federal Communication Commission) responsibilities

- A. Licenses broadcast stations and station operators
- B. Assigns broadcast frequencies
- C. Regulates operation of broadcast stations

INFORMATION SHEET

VI. RF amplifier stage in AM and FM receivers

A. Selects one carrier frequency

B. Variable tuning

C. Operates over a wide frequency range

D. Lower gain than an amplifier designed for one specific frequency

F. May be omitted from inexpensive receivers

VII. Mixer output frequencies

A. RF frequency

B. Local oscillator frequency

C. Local oscillator frequency minus RF frequency

D. Local oscillator frequency plus RF frequency

Example: If RF = 760 kilohertz and the local oscillator signal is 1216 kilohertz, the output from the mixer will consist of four different frequencies: (1) 760 kilohertz, (2) 1216 kilohertz, (3) 1976 kilohertz, and (4) 456 kilohertz

VIII. IF amplifier stage in AM and FM receivers

A. Tuned to IF frequency kilohertz

B. Amplifies a narrow band of frequencies

C. Generally consists of two or three stages of amplification

IX. AM detector stage

A. Eliminates either the positive or the negative half of the carrier

B. Filters out the RF component leaving only the message waveform

X. Limiter stage in an FM receiver

A. Removes the amplitude modulation

B. Limits the signal to a constant amplitude

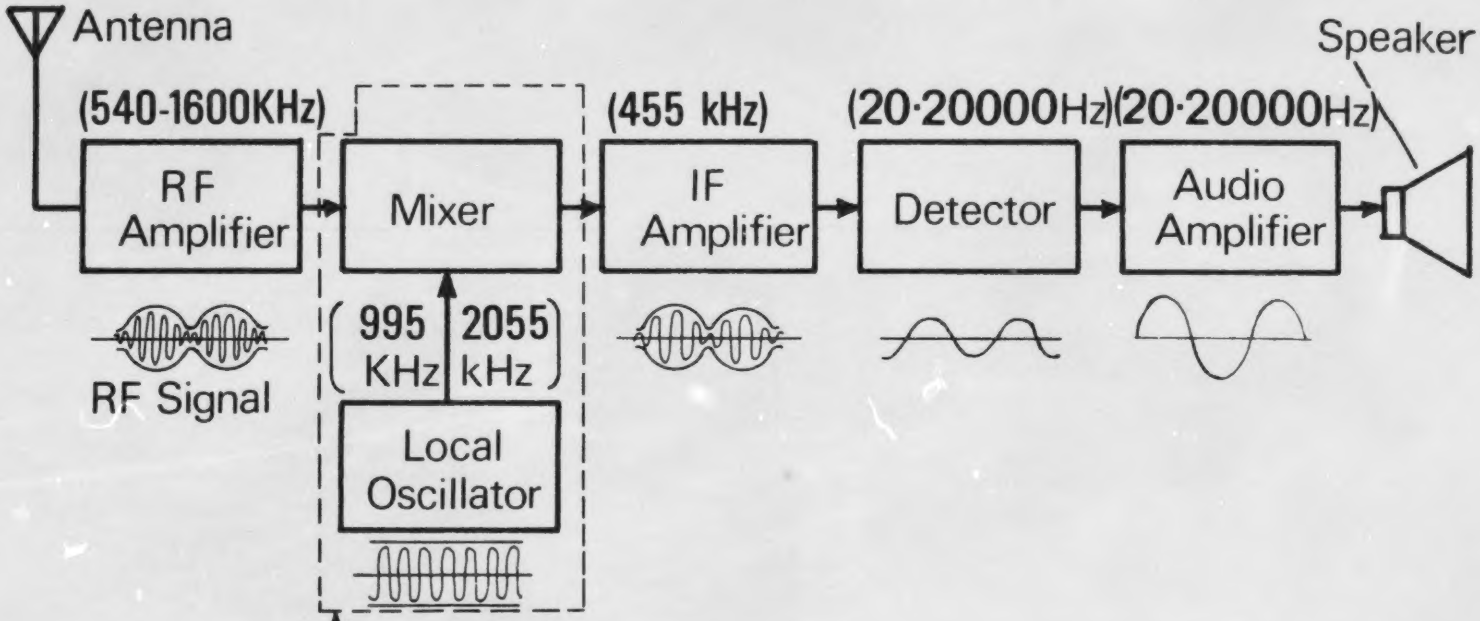
C. Removes most of the noise from the FM signal

XI. FM detection circuit

A. Known as a descriminator or ratio detector

B. Output is a function of frequency variation

AM Superheterodyne Receiver Block Diagram



Antenna

(540-1600KHz)

RF Amplifier

RF Signal

Mixer

995 KHz

2055 kHz

Local Oscillator

(455 kHz)

IF Amplifier

(20-20000Hz)

Detector

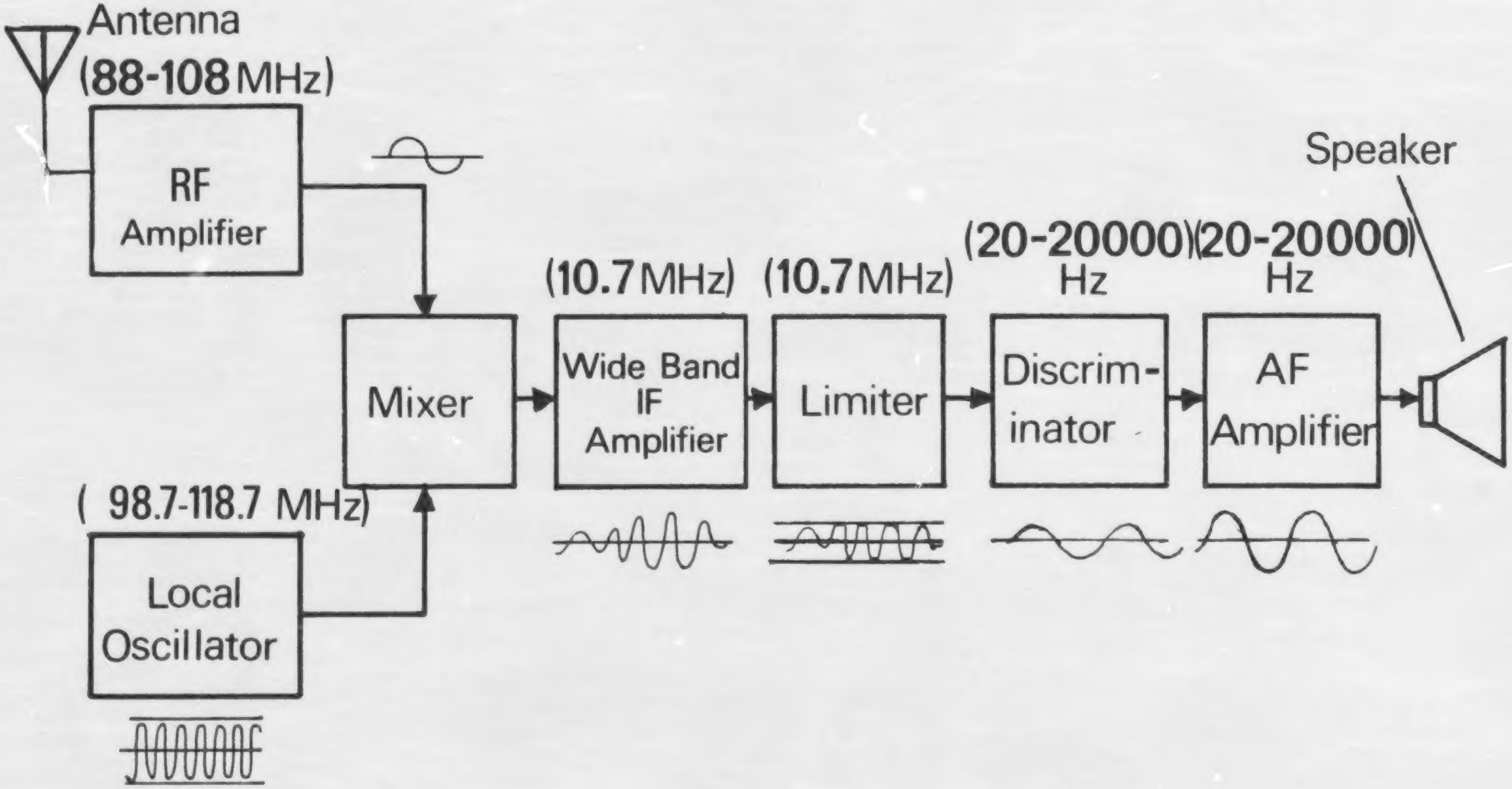
(20-20000Hz)

Audio Amplifier

Speaker

(NOTE: When oscillator and mixer are combined into one stage the result is called a converter.)

FM Receiver Block Diagram



Antenna

(88-108 MHz)

RF Amplifier

Mixer

(98.7-118.7 MHz)

Local Oscillator

(10.7 MHz)

Wide Band IF Amplifier

(10.7 MHz)

Limiter

(20-20000) Hz

Discriminator

(20-20000) Hz

AF Amplifier

Speaker

RECEIVERS
UNIT XIV

JOB SHEET #1--LOCATE AND IDENTIFY THE MAJOR STAGES OF AM/FM RECEIVERS

I. Tools and equipment

A. An available AM/FM receiver

B. Schematic diagram for the receiver (Figure 1)

(NOTE TO INSTRUCTOR: If the class is constructing a receiver kit, use the kit schematic and the kit for this job sheet.)

II. Procedure

A. Locate the power supply section in your receiver schematic

B. Determine the type of power supply used by the receiver, full-wave, half-wave, doubler, or some other type

C. Locate the power amplifier (audio amplifier) section of the receiver

D. Identify the detector section on your schematic

(NOTE: The stage preceeding the power amplifier is the detector.)

E. Locate the IF amplifier of your receiver and determine how many stages of amplification there are in the IF section

F. Locate the mixer and the local oscillator or the converter

G. Locate the AVC/AGC section

H. Locate the RF amplifier stage

(NOTE: All receivers may not have an RF amplifier section.)

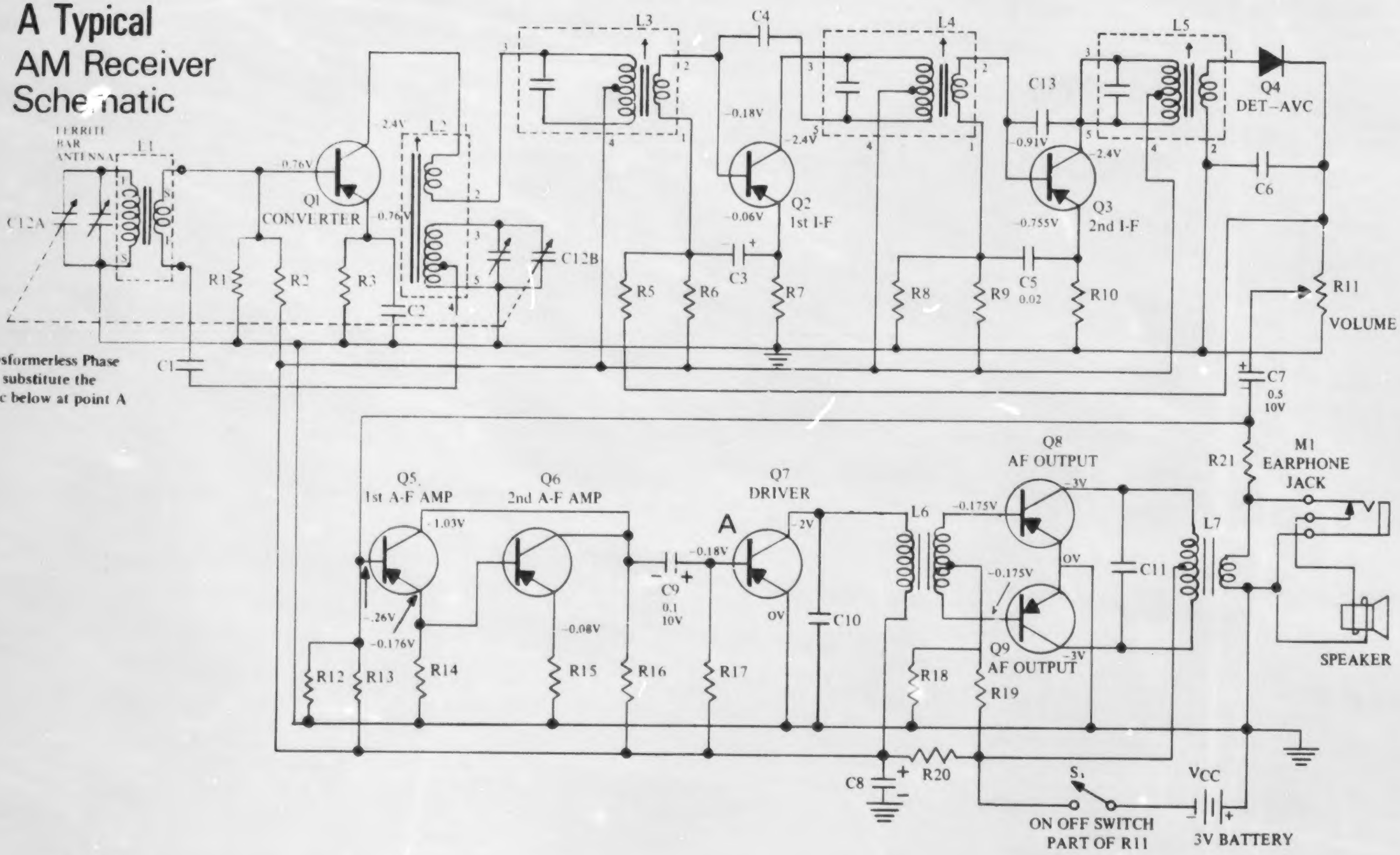
I. Identify each of the above sections of the receiver that you found on the schematic by locating it in the receiver

(CAUTION: DO NOT plug in the receiver.)

J. Locate the antenna of your receiver

Figure 1

A Typical AM Receiver Schematic


FERRITE BAR ANTENNA
L1
C12A
Q1 CONVERTER
-0.76V
-2.4V
L2
C12B
R1
R2
R3
C2
C1
L3
C4
-0.18V
Q2 1st I-F
-2.4V
-0.06V
R5
R6
C3
R7
L4
C13
-0.91V
Q3 2nd I-F
-2.4V
-0.755V
R8
R9
C5 0.02
R10
L5
Q4 DET–AVC
C6
R11 VOLUME
C7 0.5 10V
R21
M1 EARPHONE JACK
Q5 1st A-F AMP
-1.03V
-.26V
-0.176V
Q6 2nd A-F AMP
-0.08V
A
C9 0.1 10V
-0.18V
Q7 DRIVER
-2V
0V
C10
R12
R13
R14
R15
R16
R17
L6
Q8 AF OUTPUT
-0.175V
-3V
0V
-0.175V
Q9 AF OUTPUT
-3V
C11
L7
SPEAKER
R18
R19
C8
R20
S1
ON OFF SWITCH PART OF R11
VCC
3V BATTERY

For Transformerless Phase Inverter, substitute the schematic below at point A

RECEIVERS
UNIT XIV

NAME ____________________________

TEST

1. Match the terms on the right with the correct definitions.

_____a. Separates the IF from the message signal in an FM receiver

_____b. A receiver designed to receive a frequency-modulated signal

_____c. The ability of a receiver to amplify a small signal

_____d. Stage in a receiver that separates the IF frequency from the message signal

_____e. The amplifier designed to amplify the message portion of the signal

_____f. Removes or clips the upper and lower amplitude portions of the signal waveshape which removes most of the noise in an FM receiver

_____g. Assures a constant IF center frequency by keeping the local oscillator frequency separated from the RF amplifier signal by a fixed amount in FM receivers

_____h. Stage which produces an unmodulated variable RF signal

_____i. Modulates or heterodynes the RF signal from the antenna with the local oscillator RF signal

_____j. The frequency that results from mixing an RF signal from the amplifier with the local oscillator RF signal; it is then amplified by the IF amplifier

_____k. Selects a particular signal that is present on an antenna, removes the carrier frequency, and amplifies the message signal enough to drive a load

_____l. Stage which combines both local oscillator and mixer stages into one stage

1. Detector
2. AFC
3. IF
4. FM receiver
5. Mixer
6. AM receiver
7. Limiter
8. Discriminator
9. Selectivity
10. Audio amplifier
11. RF frequencies
12. AVC/AGC
13. Local oscillator
14. Receiver
15. Sensitivity
16. Converter

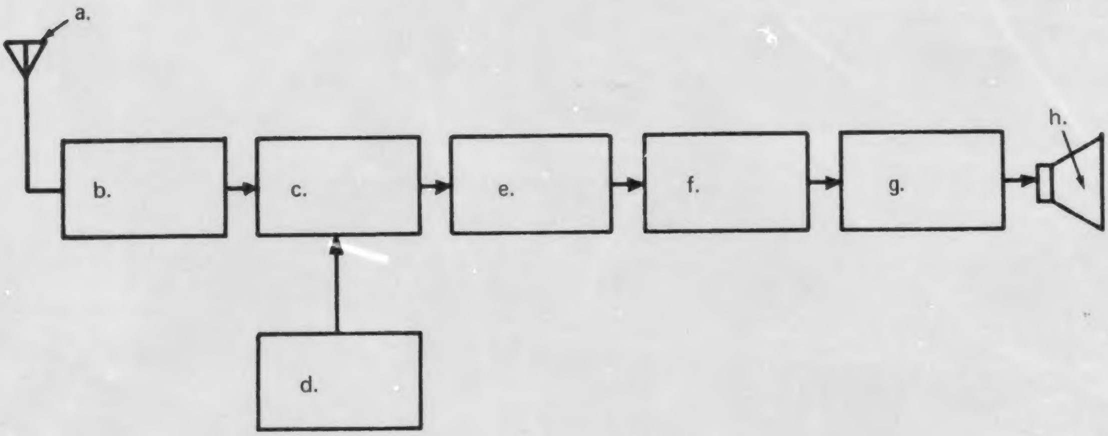
_____m. The ability of a receiver to select one signal and reject all others

_____n. A receiver designed to receive an amplitude-modulated signal

_____o. Those frequencies designated as carrier frequencies for radio systems

_____p. Increases the gain of a receiver when the signal becomes weak and decreases the gain of the receiver when the signal becomes strong

2. Identify the stages in the AM superheterodyne receiver in the block diagram below.



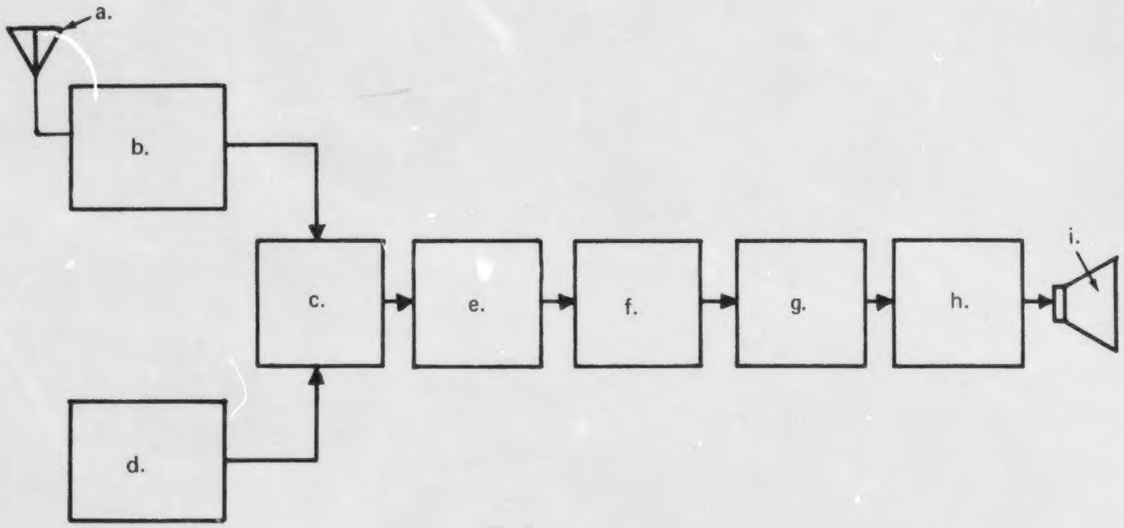
a. ______________________________ e. ______________________________

b. ______________________________ f. ______________________________

c. ______________________________ g. ______________________________

d. ______________________________ h. ______________________________

3. Identify the stages in the FM receiver in the block diagram below.



a. ______________________ e. ______________________

b. ______________________ f. ______________________

c. ______________________ g. ______________________

d. ______________________ h. ______________________

i. ______________________

4. Select the frequency ranges for AM and FM broadcast stations from the list given below by writing AM or FM in the appropriate blanks.

_____a. 20 hertz to 20 kilohertz

_____b. 88 megahertz to 108 megahertz

_____c. 30 megahertz to 300 megahertz

_____d. 535 kilohertz to 1605 kilohertz

5. Select true statements concerning the responsibilities of the FCC by placing an "X" in the appropriate blanks.

_____a. Licenses broadcast stations

_____b. Licenses station operators

_____c. Assigns broadcast frequencies

_____d. Regulates operation of broadcast stations

6. Select true statements concerning the RF amplifier stage in AM and FM receivers by placing an "X" in the appropriate blanks.

______a. Amplifies one frequency with very high gain

______b. Variable turning

______c. Must be included in all receivers

______d. Selects one carrier frequency

______e. Operates over a wide frequency range

7. State the output frequencies of a mixer stage if the RF signal frequency is 930 kilohertz and the local oscillator frequency is 1386 kilohertz.

a. ____________ kilohertz

b. ____________ kilohertz

c. ____________ kilohertz

d. ____________ kilohertz

8. Select true statements concerning the IF amplifier stage in AM and FM receivers by placing an "X" in the appropriate blanks.

______a. Generally consists of two or three stages of amplification

______b. Single stage amplifier

______c. Tuned to IF frequency kilohertz

______d. Variable frequency tuning

______e. Amplifies a wide band of frequencies

9. Select true statements concerning the AM detector stage by placing an "X" in the appropriate blanks.

______a. Eliminates both the positive and negative half of the carrier

______b. Eliminates either the positive or the negative half of the carrier

______c. Filters out the RF component leaving only the message waveform

______d. Filters out both the RF component and the message waveform

10. Select true statements concerning the limiter stage in an FM receiver by placing an "X" in the appropriate blanks.

______a. Removes the amplitude modulation

______b. Separates audio signal from RF scanner signal

______c. Limits the signal to a constant amplitude

______d. Removes most of the noise from the FM signal

11. Select true statement concerning an FM detection circuit by placing an "X" in the appropriate blanks.

_____a. Known as a discriminator

_____b. Also called a ratio detector

_____c. Output is a function of frequency variation

12. Demonstrate the ability to locate and identify the major stages of AM/FM receivers.

(NOTE: If this activity has not been accomplished prior to the test, ask your instructor when it should be completed.)

RECEIVERS
UNIT XIV

ANSWERS TO TEST

1. a. 8
   b. 4
   c. 15
   d. 1
   e. 10
   f. 7
   g. 2
   h. 13
   i. 5
   j. 3
   k. 14
   l. 16
   m. 9
   n. 6
   o. 11
   p. 12

2. a. Antenna
   b. RF amplifier
   c. Mixer
   d. Local oscillator
   e. IF amplifier
   f. Detector
   g. Audio amplifier
   h. Speaker

3. a. Antenna
   b. RF amplifier
   c. Mixer
   d. Local oscillator
   e. Wide band IF amplifier
   f. Limiter
   g. Discriminator
   h. AF amplifier
   i. Speaker

4. b. FM d. AM

5. a, b, c, d

6. b, d, e

7. Answer must show the following four frequencies; order makes no difference.

   a. 2316 kilohertz (sum)
   b. 456 kilohertz (difference)
   c. 930 kilohertz (RF)
   d. 1386 kilohertz (Local oscillator)

8. a, c

9. b, c

10. a, c, d

11. a, b, c

12. Performance skills evaluated to the satisfaction of the instructor

ELECTRON TUBES
UNIT XV

UNIT OBJECTIVE

After completion of this unit, the student should be able to identify schematic symbols for basic vacuum tubes and special tubes, identify typical characteristic curves for various electron tubes, and construct and test a vacuum tube diode circuit. This knowledge will be evidenced by correctly performing the procedures outlined in the job sheet and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to electron tubes with their correct definitions.
2. Identify the schematic symbols for diodes, triodes, pentodes, tetrodes, beam-power tubes, and thyratrons.
3. Label the pin numbers given the bottom views of tubes.
4. Identify typical characteristic curves for diode, triode, and pentode vacuum tubes.
5. Demonstrate the ability to construct and test a vacuum tube diode rectifier.

E. Test

F. Answers to test

II. References: *RCA Receiving Tube Manual*. Harrison, N.J.: Radio Corporation of America, 1973.

ELECTRON TUBES
UNIT XV

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information and job sheets.

III. Make transparencies.

IV. Discuss unit and specific objectives.

V. Discuss information sheet.

VI. Demonstrate and discuss the procedures outlined in the job sheet.

VII. Show various types of tubes.

VIII. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

- A. Objective sheet
- B. Information sheet
- C. Transparency masters
  - 1. TM 1–Schematic Symbols for Diodes
  - 2. TM 2–Schematic Symbol for Triodes
  - 3. TM 3--Schematic Symbol for Tetrodes
  - 4. TM 4--Schematic Symbol for Pentodes
  - 5. TM 5--Schematic Symbol for Beam-Power Tubes
  - 6. TM 6--Schematic Symbol for Thyratrons
  - 7. TM 7--Diode Characteristic Curve
  - 8. TM 8--Triode Characteristic Curve
  - 9. TM 9--Pentode Characteristic Curve
- D. Job Sheet #1–Construct and Test a Vacuum Tube Diode Rectifier

ELECTRON TUBES
UNIT XV

INFORMATION SHEET

I. Terms and definitions

A. Electrodes--The basic internal parts of a vacuum tube, usually consisting of cathodes, grids, and plates

B. Cathode--The electrode which emits electrons

(NOTE: The cathode is similar to an emitter.)

C. Grid--The electrode which controls electron flow

D. Plate--The electrode which attracts electrons

E. Pins--Conductors used to connect the tube's electrodes to external circuits

F. Diode (vacuum tube)--An electronic tube that has two electrodes, a cathode and a plate

(NOTE: It serves the same function as a solid state diode.)

G. Filament--A directly-heated cathode

H. Heater--A small conducting wire which indirectly heats the cathode

I. Triode--A vacuum tube containing three electrodes: cathode, plate, and control grid

J. Control grid--The grid nearest the cathode in a vacuum tube which has the greatest control over electron flow

K. Interelectrode capacitance--Capacitance between any two electrodes in a vacuum tube

(NOTE: Plate to grid capacitance, Cgp; plate to cathode capacitance, Cpk; grid to cathode capacitance, Cgk.)

L. Tetrode--A tube with four electrodes: cathode, control grid, screen grid, and plate

M. Screen grid--A grid placed between the plate and the control grid in a tetrode which helps to reduce the effects of interelectrode capacitance

N. Secondary emission--Impact emission of electrons from the plate caused by high speed collisions of cathode-emitted electrons with the plate

O. Pentode--A tube with five electrodes: cathode, control grid, screen grid, suppressor grid, and plate

INFORMATION SHEET

P. Suppressor grid--Grid placed between the plate and the screen grid in a pentode which reduces the effect of secondary emission

Q. Beam-power tube--A tube designed so that the electrons flow in concentrated beams from the cathode through the grids to the plate

R. Multiunit tube--A tube in which the electrodes of two or more tube types are placed in the same envelope

S. Gas tube--An electron tube which has the electrodes enclosed in a gas-filled envelope

T. Vacuum tube--An electron tube which has the electrodes enclosed in an evacuated envelope

U. Thyratron--A gas-filled tube that uses a grid to initiate the ionizing process of the gas

V. Thermionic emission--The "boiling off" of electrons from the cathode by thermal excitation

W. Envelope--Enclosure, usually glass, around the electrode of a vacuum tube

II. Schematic symbols for tubes

A. Diode (Transparency 1)

B. Triode (Transparency 2)

C. Tetrode (Transparency 3)

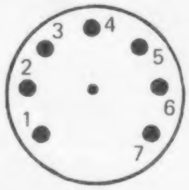
D. Pentode (Transparency 4)

E. Beam power tube (Transparency 5)

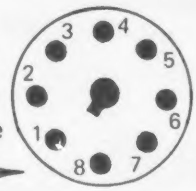
F. Thyratron (Transparency 6)

III. Tube pin numbers

A. Seven pin tube
Bottom View of Tube

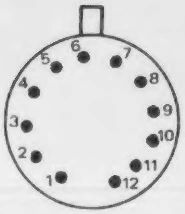


B. Eight pin tube (octal)
Bottom View of Tube

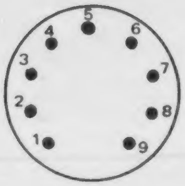


INFORMATION SHEET

C. Twelve pin compactim
Bottom View of Tube


1
2
3
4
5
6
7
8
9
10
11
12

D. Nine pin tube
Bottom View of Tube



IV. Typical characteristic curves

A. Diode (Transparency 7)

B. Triode (Transparency 8)

C. Pentode (Transparency 9)

Schematic Symbols for Diodes

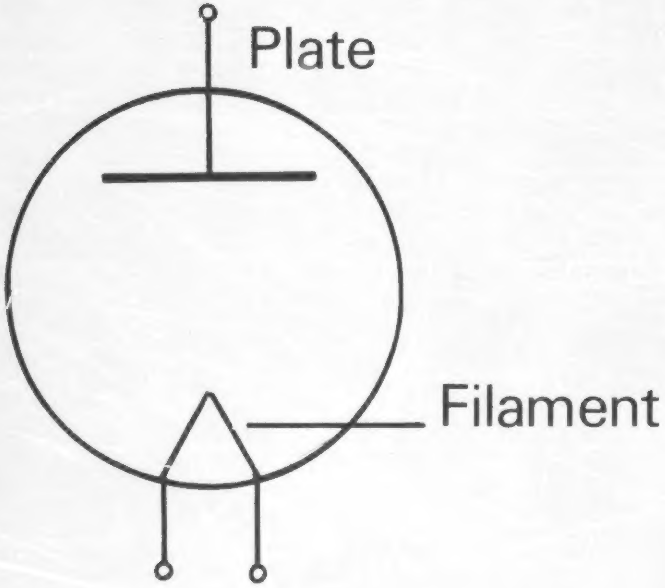


Plate
Filament

Directly Heated

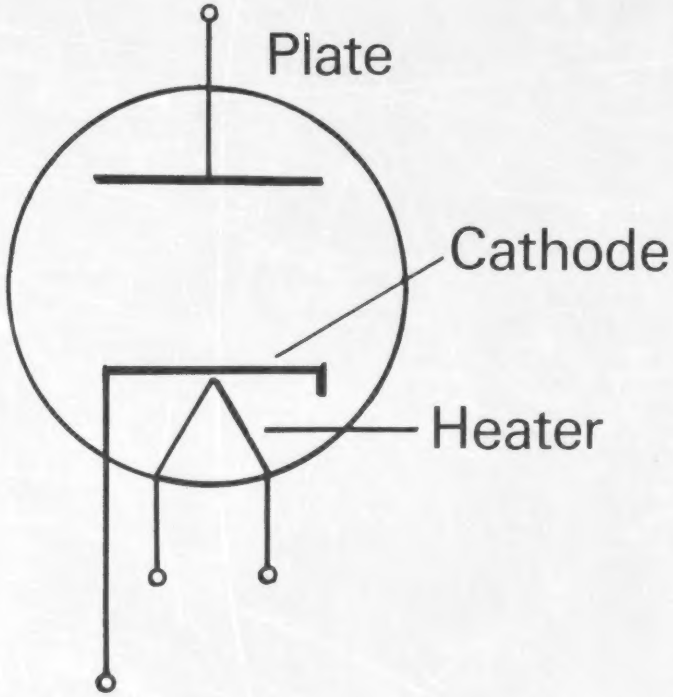


Plate
Cathode
Heater

Indirectly Heated

Schematic Symbol for Triodes

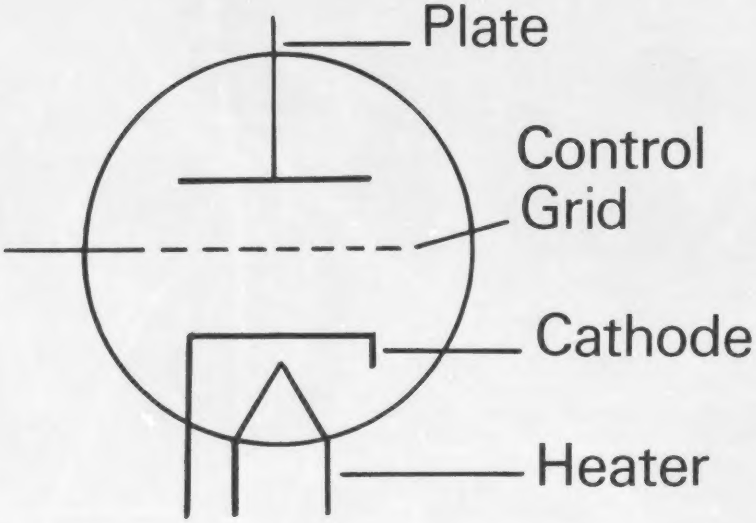


Plate
Control Grid
Cathode
Heater

Schematic Symbol for Tetrodes

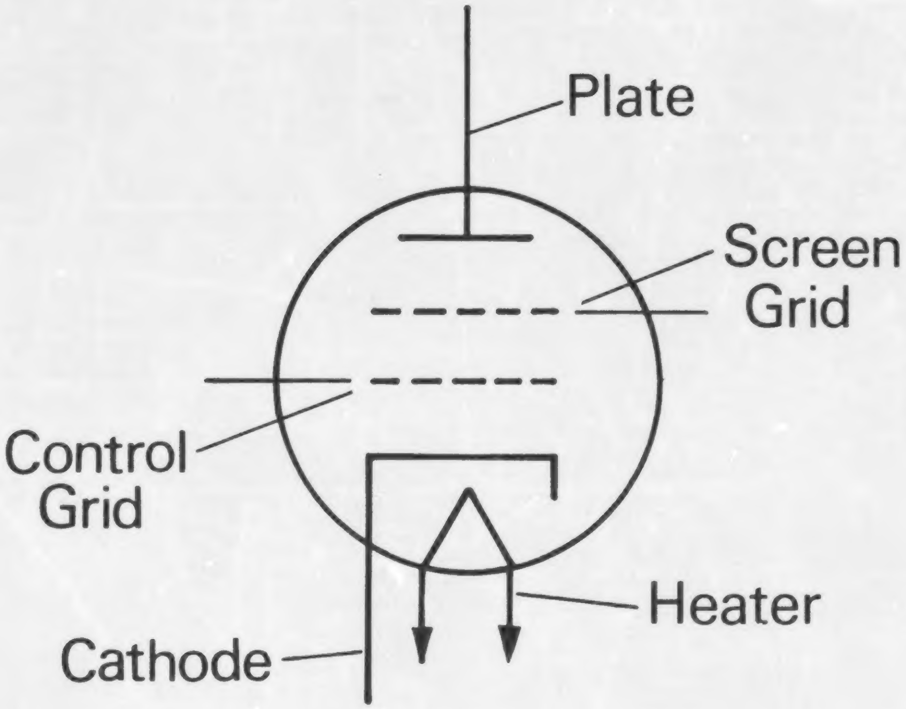


Plate
Screen
Grid
Control
Grid
Heater
Cathode

Schematic Symbol for Pentodes

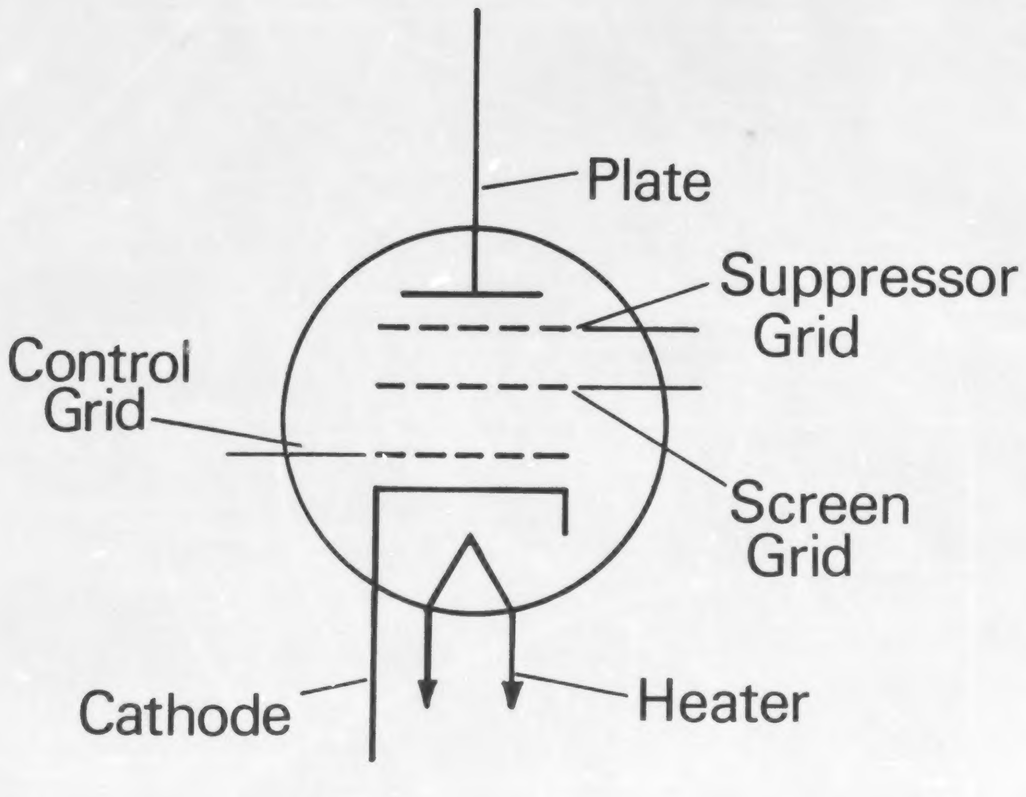


Plate
Suppressor Grid
Control Grid
Screen Grid
Cathode
Heater

Schematic Symbol for Beam Power Tubes

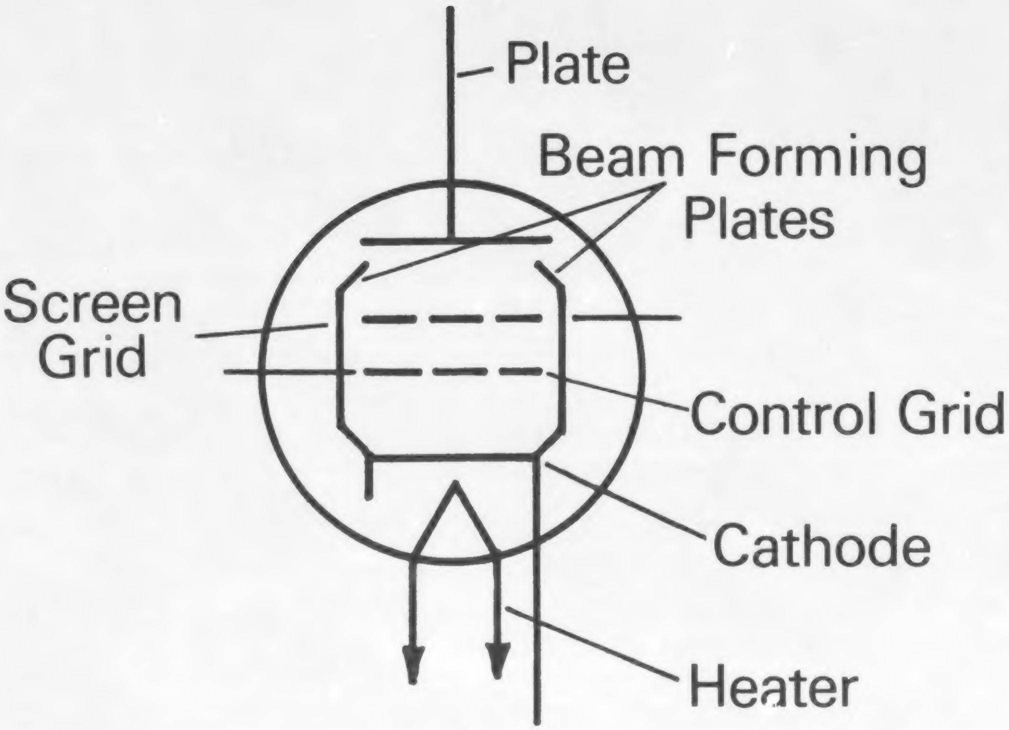


Plate
Beam Forming Plates
Screen Grid
Control Grid
Cathode
Heater

Schematic Symbol for Thyratrons

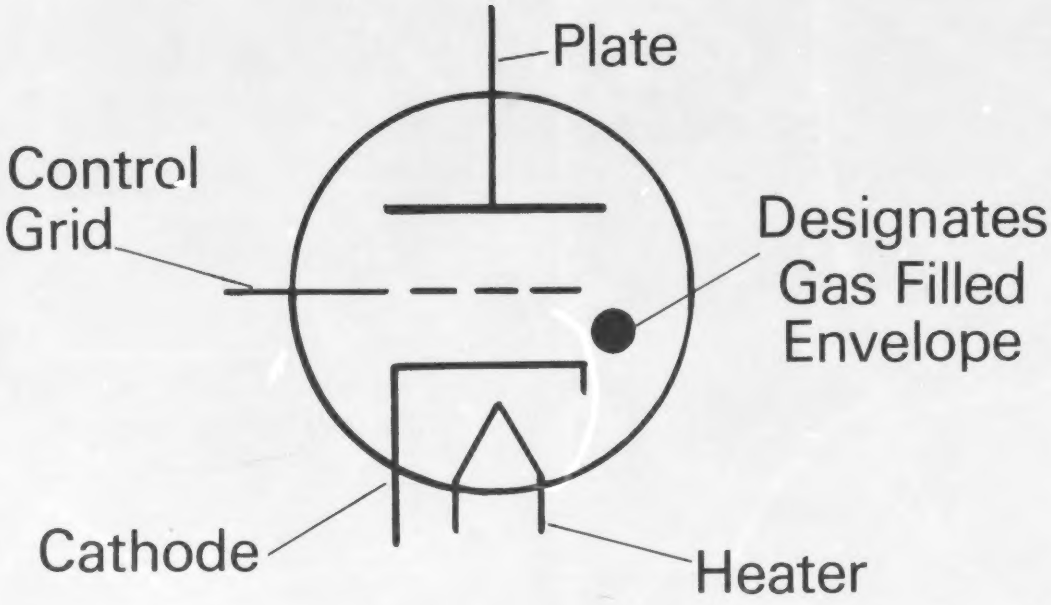
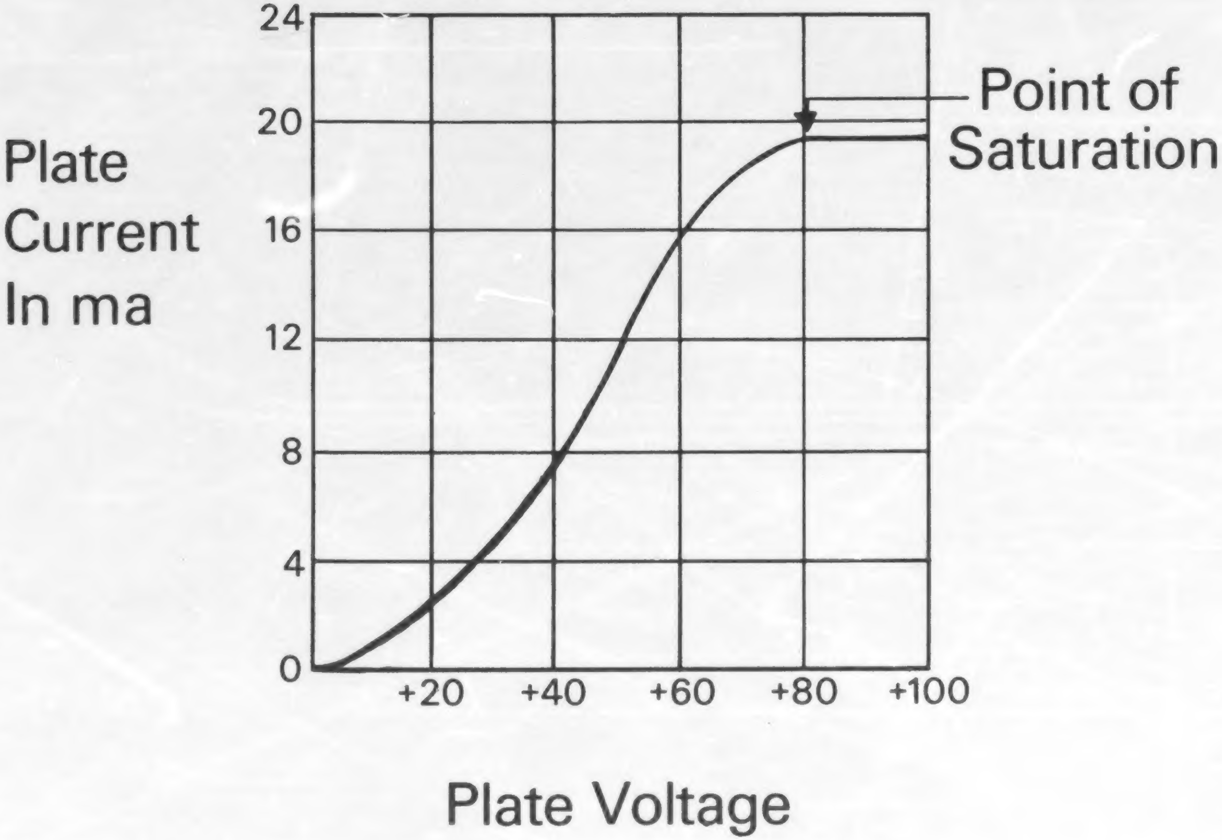


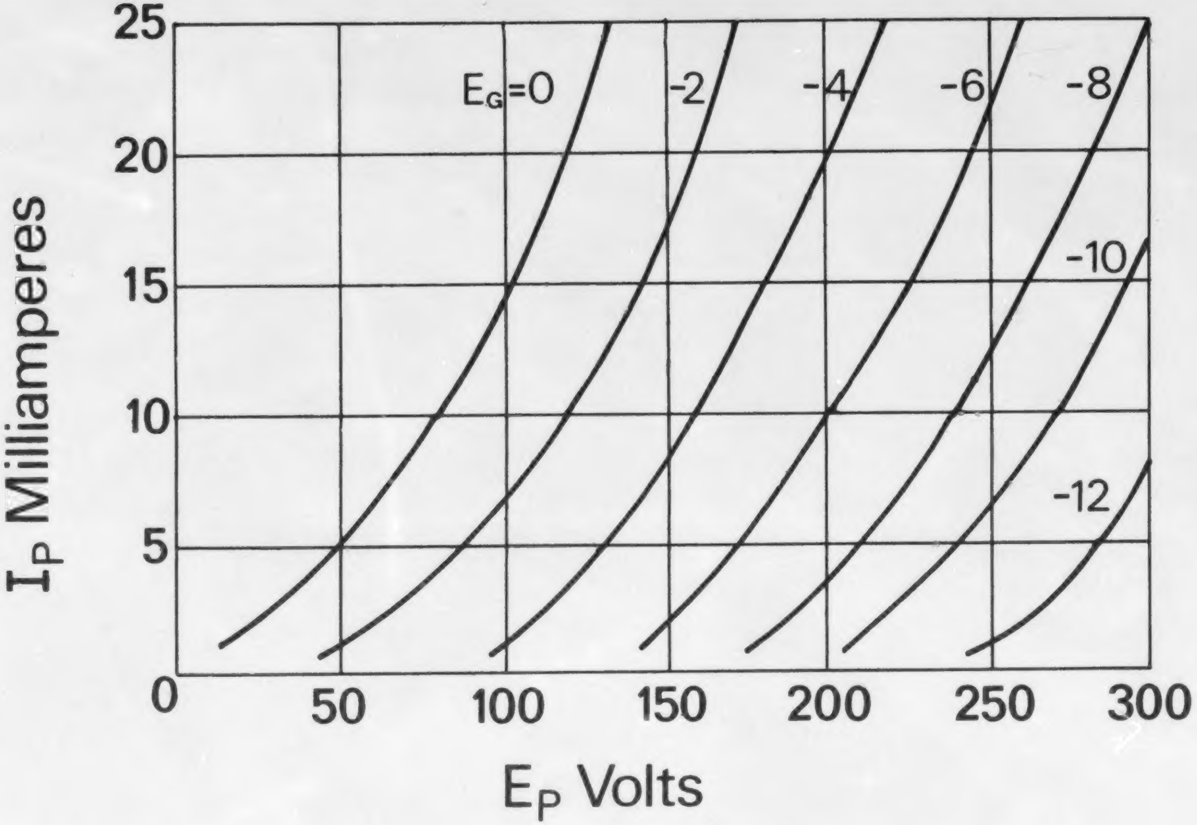
Plate
Control Grid
Designates Gas Filled Envelope
Cathode
Heater

Thyratron

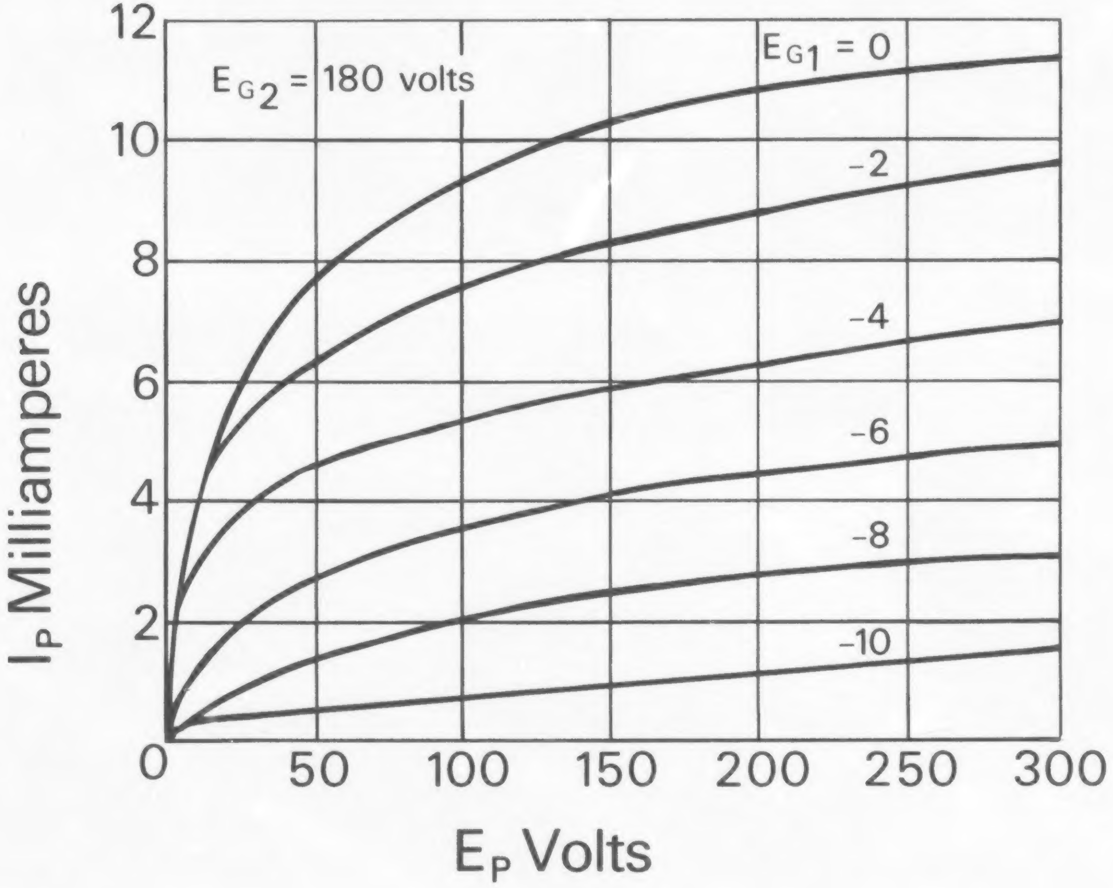
Diode Characteristic Curve



Triode Characteristic Curve



Pentode Characteristic Curve



ELECTRON TUBES
UNIT XV

JOB SHEET #1--CONSTRUCT AND TEST A VACUUM TUBE DIODE RECTIFIER

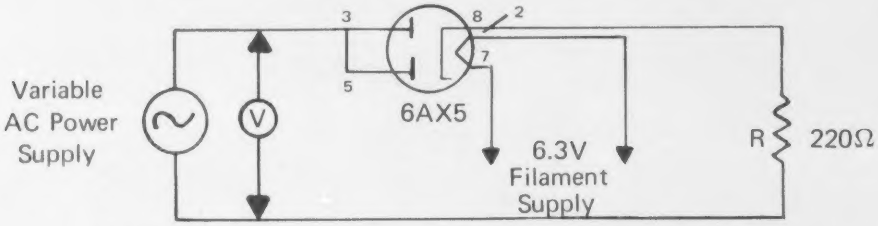
I. Tools and equipment and materials

- A. Variable AC power supply (e.g. Variac)
- B. Multimeter
- C. Oscilloscope
- D. 6.3 Volt filament power supply
- E. Vacuum diode type 6AX5 or equivalent
- F. Octal type socket
- G. Graph paper
- H. 1-10K resistor, 5W

II. Procedure

- A. Connect the circuit shown below

  (NOTE: Small numerals indicate pin numbers.)



  (CAUTION: Do not turn on the power supply until your instructor has checked your wiring.)

- B. Turn on the filament power supply and let the tube warm up for approximately two minutes
- C. Adjust the AC power supply for 110 volts as indicated on the multimeter
- D. Connect the oscilloscope across the AC power supply and adjust the oscilloscope controls until approximately two cycles appear on the screen
- E. Make a sketch of the waveshape indicating the height of the waveshape shown on the oscilloscope

JOB SHEET #1

F. Without adjusting the scope controls, move the leads across the resistor

G. Make a sketch of the waveshape indicating the height of the waveshape shown on the oscilloscope

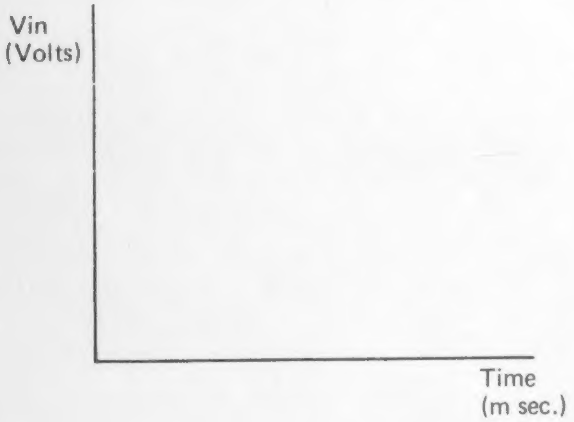
H. Compare the two sketches made in parts F and H

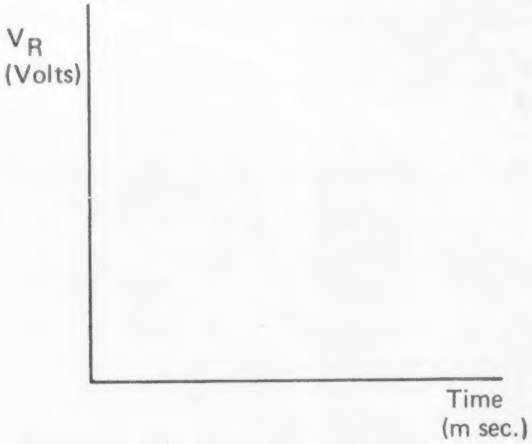
I. Using the multimeter, measure the DC voltage output across the resistor

(NOTE: Be sure to observe proper polarity.)

J. Check your results and sketches with your instructor

DATA TABLE





Measured DC Output Voltage ____________

ELECTRON TUBES
UNIT XV

NAME ______________________________

TEST

1. Match the terms on the right with the correct definitions.

_____a. The basic internal parts of a vacuum tube, usually consisting of cathodes, grids, and plates

_____b. The electrode which emits electrons

_____c. The electrode which controls electron flow

_____d. The electrode which attracts electrons

_____e. Conductors used to connect the tube's electrodes to external circuits

_____f. An electronic tube that has two electrodes, a cathode and a plate

_____g. A directly-heated cathode

_____h. A small conducting wire which indirectly heats the cathode

_____i. A vacuum tube containing three electrodes: cathode, plate, and control grid

_____j. The grid nearest the cathode in a vacuum tube which has the greatest control over electron flow

_____k. Capacitance between any two electrodes in a vacuum tube

_____l. A tube with four electrodes: cathode, control grid, screen grid, and plate

_____m. A grid placed between the plate and the control grid in a tetrode which helps to reduce the effects of interelectrode capacitance

_____n. Impact emission of electrons from the plate caused by high speed collisions of cathode-emitted electrons with the plate

1. Diode
2. Triode
3. Tetrode
4. Pentode
5. Thyratron
6. Electrodes
7. Grid
8. Plate
9. Interelectrode capacitance
10. Gas tube
11. Cathode
12. Pins
13. Filament
14. Heater

______ o. A tube with five electrodes: cathode, control grid, screen grid, suppressor grid, and plate

______ p. Grid placed between the plate and the screen grid in a pentode which reduces the effect of secondary emission

______ q. A tube designed so that the electrons flow in concentrated beams from the cathode through the grids to the plate

______ r. A tube in which the electrodes of two or more tube types are placed in the same envelope

______ s. An electron tube which has the electrodes enclosed in a gas-filled envelope

______ t. An electron tube which has the electrodes enclosed in an evacuated envelope

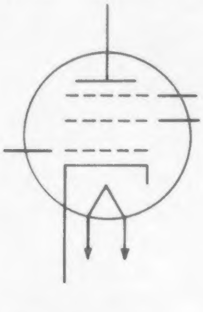
______ u. A gas-filled tube that uses a grid to initiate the ionizing process of the gas

______ v. The "boiling off" of electrons from the cathode by thermal excitation

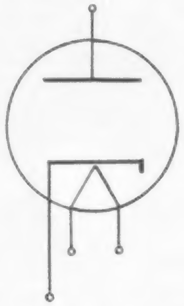
______ w. Enclosure, usually glass, around the electrode of a vacuum tube

15. Multiunit tube
16. Envelope
17. Vacuum tube
18. Thermionic emission
19. Beam-power tube
20. Screen grid
21. Suppressor grid
22. Secondary emission
23. Control grid

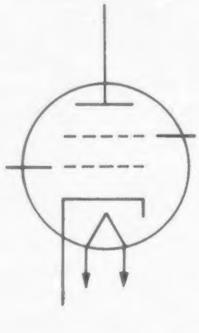
2. Identify the schematic symbols for diodes, triodes, pentodes, tetrodes, beam-power tubes, and thyratrons from the schematics that follow.



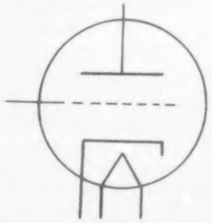
a. ______



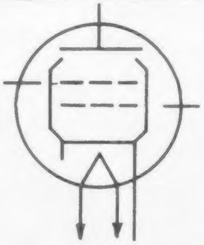
b. ______



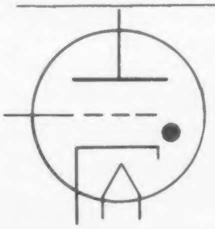
c. ______



d. ______



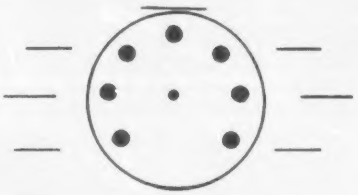
e. ______



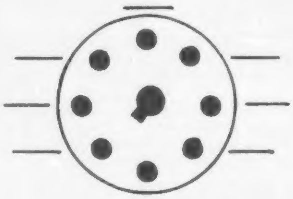
f. ______

3. Label the pin numbers of the tubes shown below.

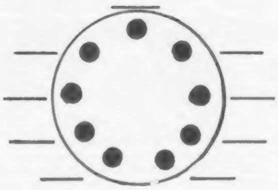
a.



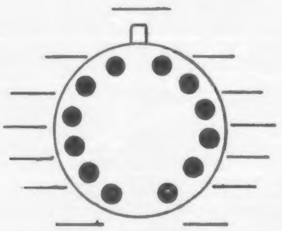
b.



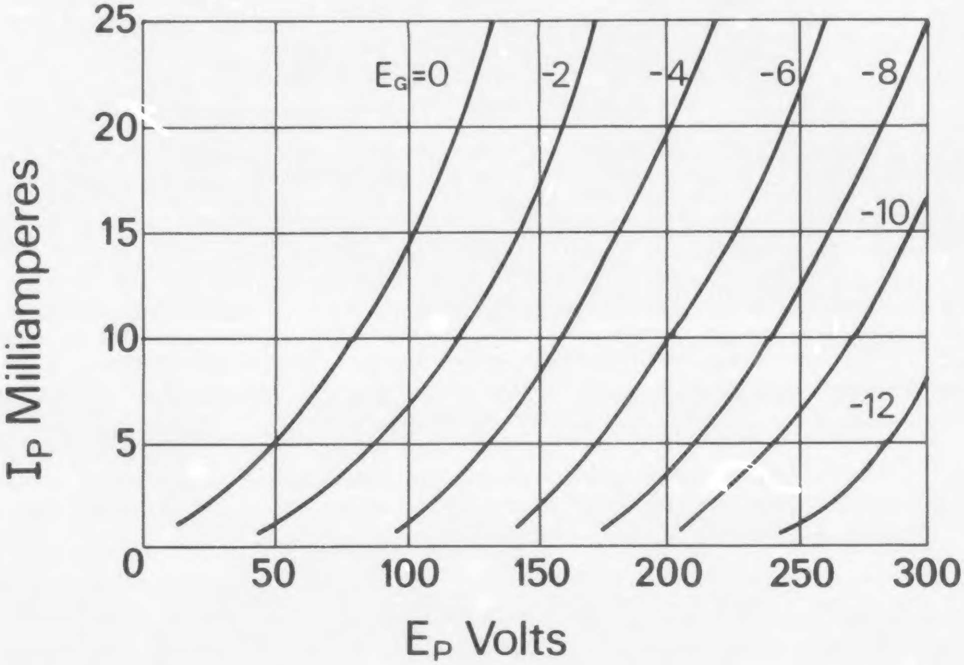
c.



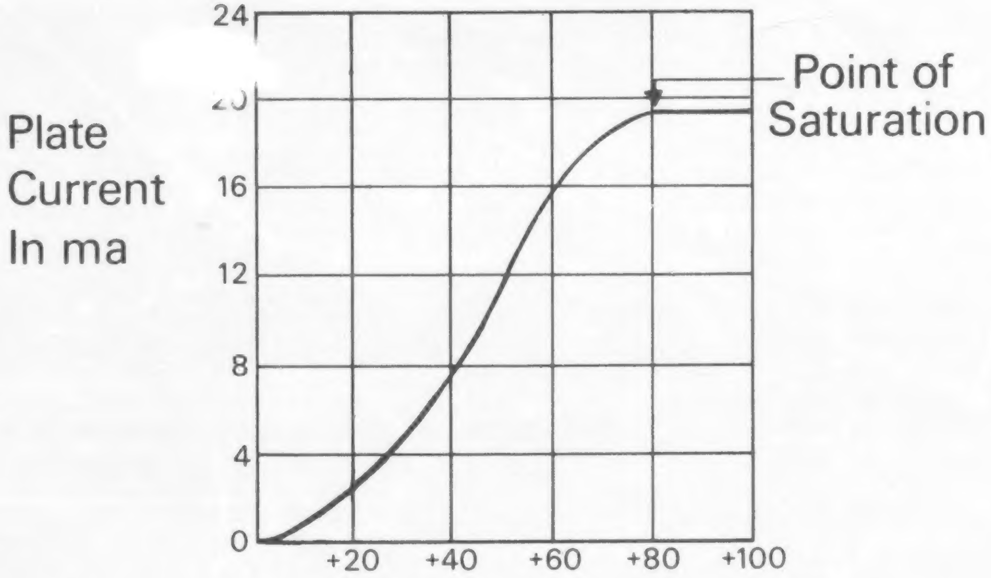
d.



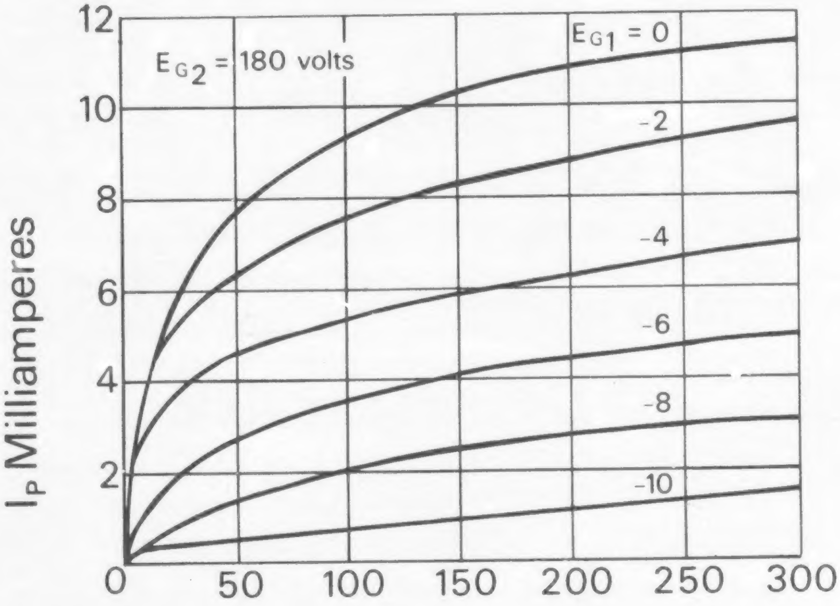
4. Identify typical characteristics curves for the diode, triode, and pentode vacuum tubes shown in the diagrams that follow.



a. ______________________________



b. ______________________________



c. ______________________________

5. Demonstrate the ability to construct and test a vacuum tube diode rectifier.

(NOTE: If this activity has not been accomplished prior to the test, ask your instructor when it should be completed.)

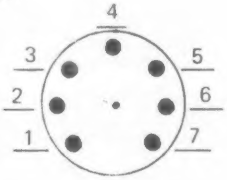
ELECTRON TUBES
UNIT XV

ANSWERS TO TEST

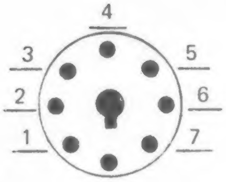
1.
   - a. 6
   - b. 11
   - c. 7
   - d. 8
   - e. 12
   - f. 1
   - g. 13
   - h. 14
   - i. 2
   - j. 23
   - k. 9
   - l. 3
   - m. 20
   - n. 22
   - o. 4
   - p. 21
   - q. 19
   - r. 15
   - s. 10
   - t. 17
   - u. 5
   - v. 18
   - w. 16

2.
   - a. Pentode
   - b. Diode
   - c. Tetrode
   - d. Triode
   - e. Beam-power tube
   - f. Thyratron

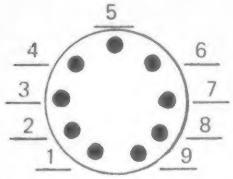
3.
   - a.



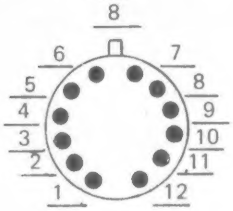
   - b.



   - c.



   - d.


8
6
7
5
8
4
9
3
10
2
11
1
12

4.
   - a. Pentode
   - b. Diode
   - c. Triode

5. Performance skills evaluated to the satisfaction of the instructor